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March 1988

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CHANGE IN THE STATE OF THE SEXUAL GLANDS OF TEREK TROUT WHEN BRED IN SEA WATER

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A study was made of the state of the sexual glands of immature /3*
Terek trout that were held in traps constructed in Izberbash harbor in the Caspian Sea. The traps were protected from the direct action of waves by banks of rocks set close together. The traps were made from netting with a mesh of 5 to 10 mm and they were 7 x 3 x 2.5 m in size. /4
The salinity of the water in the area where the traps were installed was 11 to 12 per cent.

A group of abiotic factors, (including salinity, temperature, and oxygen content) which are either absent or have a different significance in a fish hatchery, influenced the fish that were being grown. As a result there was a change in a number of indices, including growth, survival, and the state of the osmoregulatory system.

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One of the important consequences of keeping immature fishes in the sea is a significant increase in the proportion of smolts or silvery fish, in comparison with those kept in fresh water, amounting to 70 to 80 per cent - their number in comparable batches at a fish hatchery does not exceed 40 per cent. The high percentage of silvery immatures in the sea indicates not only that the females smoltify, as occurs in fresh water, but the males do as well. The proportion of males among the smolts in the sea water amounts to 38 per cent on average, while in fresh water it is only 6 to 9 per cent. The gonads of these fishes are most commonly at stages I or VI-I of maturation, just as in wild smolts. Sexually immature males that are more mature and individuals with gonads in a post-spawning condition are encountered among the parrs.

The fish in the sea water exhibit a significant decrease in the absolute and the relative weight of the testes, which is due both to the growth rate of the juveniles and to the influence of a group of abiotic factors on spermatogenesis, resulting in a delay in the development of the gonads of sexually immature fishes and an acceleration in the restorative processes of individuals maturing earlier. The number of juvenile males is twice as great and the proportion of maturing fishes (stage III of maturation) is three times less in sea water than it is at a hatchery. The weight of the gonads of males in a post-spawning condition at release is significantly less in sea water than in a hatchery (p 0.001).

When fishes with gonads at stage III of maturation are released into the traps in the autumn, their spermatogenesis terminates completely in approximately the same period of time as it does at a hatchery. When breeding fishes with less developed gonads, however, the number of

matured males in the traps is lower than in fresh water, and the sexually immature males become smolts, which is something that can never be achieved when they are bred at a hatchery.

"Ripe" males do not perish in the salt water; they feed normally and grow. This provides grounds for suggesting that freshwater males can live in the sea and grow to commercial size and then return to spawning as large migratory adult fishes.

Significant changes of the magnitude that occur in the state of the sexual glands of males do not occur in females. Females with gonads in stages I and II of maturation predominate among silvering immatures in sea water and in fresh water; the oocytes of the older generation in the majority of these fishes correspond to degree 4 of PPR [*expansion uncertain; possibly: degree 4, index of sexual development - Tr.*]. The proportion of fishes with gonads at stages II and III of maturation (degree 5 PPR) is only half as much among parrs in the traps than it is in fresh water. The diameter of the oocytes and the weight of the gonads is significantly lower in males in sea water than in males at a hatchery.

When bred in autumn, no differences were found in the degree of development of the ovaries of immatures in sea water and those in a hatchery. The state of the sexual glands of smolts and of those turning silver corresponded to stage II of maturation, just as in the spring.

In summary, a benefit is only obtained from keeping immatures in sea water if the fishes released into the traps are in the initial stages of gametogenesis. When the state of the sexual glands is more advanced, then gametogenesis proceeds just as it does in fresh water. The considerable increase in the proportion of silvery immatures and

the greater number of males with gonads among them (characteristic of migratory individuals) allows us to view the growing of Terek trout in sea water, especially in the spring, as a biotechnical device to produce an increased proportion of smolts.

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THE ACCELERATED BREEDING OF SMOLTS OF THE NORTHERN POPULATION OF ATLANTIC SALMON (Salmo salar) THROUGH THE USE OF HEATED WATER

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Successful cultivation of Atlantic salmon in the inshore zone /16*
of the White and Barents seas requires accelerated methods for obtaining quality stocking material - smolts. One of the universally recognized methods for accelerating the growth and development of fish is an optimally controlled temperature regime. We are aware of Soviet studies on the development of Atlantic salmon embryos at various constant temperatures, but all of these studies examine the effect of enhanced temperatures on the growth and development of Atlantic salmon in the embryonic and early postembryonic periods, without considering the later stages of growth.

We have studied the effect of heated water on the growth of At- /17
lantic salmon immatures from larvae to fingerlings. Accelerated

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offspring were obtained and raised to the yearling age in artificially heated water, which was maintained at a constant temperature of 6.5° C. To serve as a control, a portion of the eggs from the same batch were incubated at the naturally occurring temperature of the nutrient water supply, and there was no artificial heating of the water after hatching. The biological and morphometric indices of the accelerated immatures (the experimental group) were calculated and compared with the growth and development indices of the offspring grown without heating (the control group).

Wooden troughs were used for incubation, two of which were equipped with individual heating units. The water discharge in the experimental and control troughs was 9.5 L/min and 11 L/min and the oxygen content was between 8 and 8.8 mL/L.

Postembryos were maintained and larvae were grown according to the instructions of the State Scientific Research Institute of Lake and River Fisheries.

For breeding tanks we utilized plastic tanks 2 x 2 m in size. The discharge of water in the tanks equipped with individual electric heating units did not exceed 7 to 9 L/min, with a depth of 13 to 17 cm; water discharge in the unheated tanks was between 15 and 17 L/min. The stocking density for the experimental and control immatures with a mass of 1 g was between 1000 and 3000 per square meter and it was 1000 per square meter in the case of fish of more than 1 g. The oxygen content in the tanks with artificially heated water varied from 6.5 to 7.5 mL/L and the pH was approximately 7. During the period of the essential growth of the accelerated immatures the water temperature in the

experimental tanks was maintained at 10° to 14° C. It was found that the development of embryos in the experimental group was completed at the age of 75 days or at 504° days after fertilization. The length of time for embryo development to hatching under natural temperature conditions came to 212 days or 311° days. The experimental and control post-embryos, as well as the fingerlings that developed, had the same mass and the same body length for all practical purposes. Variability in body length was less for the larvae in warm water than for those in cold water, while variability in mass showed no significant differences in either case. Mortality during this period of time was significantly higher in the experimental group of immatures than in the control group, amounting to 16.5 per cent and 1.5 per cent, respectively. The experimental group and the control group did not exhibit any difference during subsequent growth. The results of a complete biological analysis of the cultivated immatures at the age of 10 months showed that the experimental fish matched the control fish in terms of their physiological condition; the internal organs showed no signs of any irregularity in development. /18

Forty per cent of the fish examined from among the accelerated immatures of the Tuloma population developed according to the same pattern as freshwater males.

When released for wintering at the age of 10 months, the range in variation in body mass among the fish in the experimental group was significant. Thus, while the average mass was 5 g, the foremost individuals attained 18 to 20 g and had smoltified completely (the body mass of the control fish was 1 to 1.5 g).

The use of heated water to accelerate the cultivation of Atlantic salmon smolts in the Arctic has shown promise.

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CHARACTERISTICS OF THE ECOLOGY OF SPAWNING AND EGG INCUBATION: SOCKEYE OF LOCAL ISOLATES REPRODUCING ON SPAWNING GROUNDS OF VARIOUS TYPES IN THE LAKE AZABACH'YE BASIN

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The spawning of brood stocks of the sockeye population of Lake /20*
Azabach'ye, which includes more than 50 subisolates, takes place on three basic types of spawning grounds: (1) lakes, (2) rivers, and (3) klyuches or "bowls" [Konovalov, 1980] *[Note: a klyuch is a slow flowing, spring fed creek or an abandoned river channel, sometimes with lake-like expanses; many klyuches in Kamchatka are used by salmon for spawning.]* The characteristics of the water supply cycle that provides the environment for spawning and for egg incubation were studied at 28 spawning grounds between 1979 and 1985. As a result, the variability from place to place, season to season, and year to year was established for the following features of water bodies used for spawning: (1) the level; (2) the velocity of flow; (3) the run-off; (4) the content of oxygen dissolved in

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the water; and (5) the pH and the temperature of the water in the bottom (spawning redds) and at the surface.

The maximum values for water level, velocity of flow, and run-off was observed at all spawning grounds to be in the first half of July (the commencement of spawning by early races of sockeye); minimum water content appears in April. During that period the water level at spawning grounds in lakes drops by 1.5 to 2.0 m, while in rivers and klyuches it only drops by 0.10 to 0.20 m. The annual flow distribution shows considerable variation, even among spawning grounds of the same type; thus, for example, the values for water level and run-off decrease by factors of three and six, respectively, at the Kultuchnaya River, while at the Letnaya the corresponding values decrease by factors of 0.5 and 1.5. The average rates of flow in the period of the maximum in rivers and at the outlets of klyuches are 0.1 to 0.7 m/sec, while at the low water period it decreases to less than half. The content of dissolved oxygen in the water at the surface of water bodies varies during the spawning period between 8.0 and 11.5 mg/L at different spawning grounds. It is 0.2 to 0.8 mg/L less in spawning redds (at a depth of 20 to 40 cm), and towards the end of incubation is drops at certain spawning grounds to 1.2 to 1.7 mg/L. The pH value of the water from different spawning grounds varies from 6.8 to 8.7, while in different parts of one and the same spawning ground it differs by 0.1 to 0.3. As a rule, the pH value of the bottom water is the same as that of the surface water - the difference does not amount to more than 0.1 or 0.2. The water temperature in spawning rudds (T_{sr}) depends on the temperature

of the surface layer of water (T_s), which is due to the filtration of /21
the surface waters and their subsequent heat exchange with the bottom waters. The relationship between the annual variation of T_{sr} from T_s and the daily air temperatures (T_a) was found for each type of spawning ground, making it possible to determine the rates and time periods of embryonal and larval development on the basis of data about T_a. Observations for spring sockeye showed daily variations of 1.5° to 3.3° in T_{sr} (in the spawning period), with a range in daily variations of T_s of 3.0° to 7.0°, and of T_a from 9.5° to 26.8°. Daily variations in T_{sr} at spawning grounds in lakes was very insignificant (0.1° to 0.2°). During the first half of the incubation period (August to October), the average value of T_{sr} came to about 4.6° for spawning grounds in lakes, which was somewhat greater than at klyuches and rivers (2.8° and 3.9°). When T_a at klyuches became negative there was an insignificant drop in T_{sr} (by 0.5° to 1.0°), while at river and lake spawning grounds it remains in the neighborhood of 0° (0° to 0.8°) throughout the entire winter period. And so, each type of spawning ground is characterized by its own rates and - naturally - its own periods of embryonal and larval development.

By and large, spawning grounds at klyuches, rivers, and lakes are differentiated by various elements in the water supply system that influence the formation of the biological structure of the subisolate and the dynamics of its numbers.

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CHARACTERISTIC FEATURES OF REGULATING THE LIFE CYCLES OF SALMONIDS IN RELATION TO THE PROBLEM OF SALMONICULTURE

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In order to formulate ways of controlling the life cycle of salmonids and to establish a rational salmon industry, it is first necessary to explain the regulating mechanisms that determine the attainment of the different stages in the complex life cycle of salmonids. A considerable amount of basic data has been collected in recent years in regard to the role of ecological and hormonal factors and in regard to regulating the life cycle of fish with different ecologies, including salmonids [Barannikova, 1981 and 1984; Donaldson and Hunter, 1983, data cited]. /21*

Regulation of the reproductive function in the final stages of the sexual cycle is achieved in a similar manner among different species of salmon that reproduce at low temperatures in the autumn period. The chum of the Amur River and of rivers of varying length on Sakhalin Island /22

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have been employed as an example to demonstrate the dynamics of gonadotrophic and genital steroid hormones when the gonads are in transition from stage IV to stage V of maturation. Hormonal characteristics are determined chiefly by the condition of the gonads and not by ecological factors (sea or river) in the period preceding maturation. Information on the hormonal mechanisms that regulate the reproductive function has been employed to stimulate the maturation of salmonids. At the present time, salmon are retained at a hatchery in order to obtain mature sex cells from them for different periods of time, ranging from a few days up to several months (in the case of hiemal forms), depending on the particular ecological characteristics of the forms that are being propagated. Under these conditions we do not control the process of maturation of the adult fish. Various hormonal products (including pituitary compounds and hypothalamic neurohormones) are employed at the present time in order to synchronize this process among the different fish and in order to accelerate the maturation process [Van der Kraak, 1983; Barannikova et al., 1987 and 1988]. The action of sexual steroids is used in order to lengthen the period of male functional maturity among some salmonid fish [Khristoforov et al., 1985]. Considerable success has been obtained in controlling the shaping of the sex composition in salmon populations [Donaldson, 1982 and 1983].

A crucial central stage in the life cycle of a number of salmon species is that of smoltification, when the immature undergoes preparation for a change in the environmental conditions of its habitat. The functional mechanisms of smoltification have been studied on the basis of different species and different ecological forms, and the characteristics of this process in salmon and trout from various populations have

been identified in part. One of the most important indicators of salmonid readiness for life in the sea is the development of the mechanisms that regulate osmosis [Barannikova, 1975; Barannikova et al., 1976 and 1983; Krayushkina, 1983; and Chernitskii, 1983].

When salmonids are bred at a fish hatchery, utmost importance attaches to a correct formulation of the standard for managed fish production and for the release into natural water bodies of physiologically full-fledged juveniles capable of adapting to the environment of their new habitat and capable of extensive adaptive reactions. Completed studies have shown that smolts, young fish in the process of smoltification, possess such qualities. There occurs in early ontogenesis in a number of salmonid species, especially in pink salmon and chum (the genus Oncorhynchus), a rapid growth of adaptive capabilities that provide, in particular, an enhanced euryhaline capacity; nevertheless, the process of smoltification in those forms with a brief period of life in a river has its own significant features.

A clearly defined stage of smoltification exists in a number of /23
salmonids. It has been demonstrated in the case of the Caspian inconnu [Stenodus leucichthys leucichthys] that the immature is able to adapt to 10 to 12 per cent salt water at an early age (25 days; weight: 0.6 g); its adaptive capabilities increase somewhat with age. The process of adaptation is achieved in conjunction with mechanisms that regulate neurohormones.

When the process of reproducing salmonids is intensified, significant results can be obtained by employing higher temperatures and a longer photoperiod. It must be kept in mind that it is necessary to

employ different types of management during the course of salmonid life cycles in those instances when populations are being formed for natural reporduction or when commercial breeding is being carried out.

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INDUCING THE MATURATION OF FEMALE CHUM BY USING HORMONES

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Given the necessary ecological conditions, salmonids are capable /25* of maturing at fish hatcheries without supplemental inputs. At present, salmon are maintained at the hatchery over differing periods of time - from a few days to a number of months and even up to a year (in the case of hiemal forms), depending on the ecological characteristics of the forms being bred. In such cases the maturation process in the brood stock is neutral, which makes frequent scanning of all the fish imperative in order to identify mature individuals. This reduces the effectiveness of fish management.

New data has recently been obtained regarding the hormonal regulation of the processes of development and maturation of the sexual glands of fishes. On the basis of these data methods have been

*Translator's note: Numbers in the right-hand margin refer to the corresponding page in the Russian text.

developed for controling the reproductive functions [Barannikova, 1981 and 1984; Donaldson and Hunter, 1983, data cited]. Autumn chum of the Amur River were exposed to the action of hormones intended to induce maturation and ovulation, in September at a water temperature of 6° to 9.5° C. The females utilized in the experiments had gonads in maturation stage IV, their gonadosomatic index was 11.6±0.5 per cent, and the diameter of the oocytes was 5.59 ± 0.08 mm. The injection of glycerin hypophyseal compound obtained from the hypophyses of chum (two injections, 40 units per kilogram, cumulative dosage) produced accelerated maturation and ovulation in comparison with the control.

After a double administration of superactive lyudiberin analog (LHRH-A) in the amount of 46 or 54 mcg/kg (with a 3 day interval between injections), by the 8-10th day after the start of the experiment, the number of females with ovulated eggs was 75-100%, which is considerably more than in the control (12-33%). The use of lower doses of LHRH-A (15 mcg/kg) did not exert a stimulating effect on the maturation of the fishes. However, when pimozide, a dopamine blocker was administered first, the subsequent effect of the same low doses of LHRH-A stimulated the maturation and ovulation of chum females.

Egg diameter (5.96±0.04mm) and the gonadosomatic index (15.5±0.5%) of females which matured under the influence of the hormonal preparations did not differ in the different variants of the experiments, but proved to be somewhat lower than the /26 corresponding indices in autumn chum females of a nearby

population (Lower Uda R.), which had matured in natural conditions up to that time. The gonadosomatic index was not reliably altered by comparison with the control females in the IV stage of maturity, but the egg diameter had increased ($P<0.05$). Observation of the experimental batch of fertilized eggs, larvae and fry during the premigration period obtained as a result of LHRH-A stimulation of the maturation of females did not show deviations in their development. Accelerated maturation and ovulation of chum salmon has been produced by the use of hormonal influences; the use of LHRH-A is obviously justified in improving the effectiveness of brood stock work in salmon breeding.

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CONCENTRATION OF GONADOTROPIN IN THE BLOOD SERUM OF AUTUMN CHUM ONCORHYNCUS KETA MIGRATING TO SPAWN INTO THE RIVERS OF SAKHALIN

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In order to determine the peculiarities of the hormonal regulation of the reproductive function in autumn chum, the concentration of hypophysial gonadotropin was determined in blood serum of males and females migrating into rivers of Sakhalin I. differing in remoteness of spawning grounds from the mouth. /26*

Autumn chum individuals caught at the mouth of the Tym' R., one of the longest rivers on Sakhalin, in September are characterized by silver body coloring, the gonads of most of the fish being in the III stage of maturity. The gonado-somatic index of the females in this period was 10.5± 0.5%, while the egg diameter was equal to 5.48±0.22 mm. The gonado-somatic index of females caught at the mouth of the river, was 5.14± 0.28%.

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A determination of gonadotropin in blood serum performed by means of radio-immunological analysis, showed that the hormone level during this period of the migration is low and in females amounts to 3.3±0.4 ng/mL (n=29), and in males 3.2± 0.3 ng/mL (n=23).

Females caught in the region of Ado-T'movo settlement (200 km above the mouth) and at Kirovskoe settlement (300 km from the mouth), with gonads in the IV and V stages of maturity, had gonadosomatic index and egg sizes which did not differ reliably. In fish in the IV stage of maturity, the gonado-somatic index was /27
20.5±0.9%, the egg diameter was 6.66±0.11 mm, while in females with gonads in the V stage of maturity, the gonado-somatic index was 19.5±0.6% and the egg size was 6.87±0.13 mm. The concentration of gondatropin in blood serum in females in the IV stage of maturity was 8.7±0.7 ng/mL (n=12), which is reliably higher than in fish caught at the mouth with less mature gonads ($P<0.001$). In females with ovulated eggs (V stage of maturity of the gonads), the level of gonadotropin was still higher (15.4±1.6 ng/mL) (n=33). In males, according to the maturation of the gonads, the level of gonadotropin in blood serum remained at a comparatively low level (IV stage of maturity - 1.0±0.4 ng/mL (n=10), V stage of maturity - 3.0±0.7 ng/mL (n=46), increasing somewhat on the transition of the gonads of the fish from the IV to the V stage of maturity ($P<0.05$).

A considerable increase in gonadotropin concentration in blood serum is noted in chum males and females soon after spawning. The level of hormones increases by 3-4 times in comparison with that in individuals during spawning and is 42.4±6.1 ng/mL in females (n=14), 13.3±3.2 ng/mL in males (n=23).

In autumn chum which enter the Zavetinka, a small river in Southwestern Sakhalin, for spawning, the gonads were close to maturity, while a substantial part of the females had ovulated eggs. The gonado-somatic index of the females in the V stage of maturity was 20.7±0.4%, while the diameter of eggs was 6.88±0.10 mm.

Analysis of gonadotropin concentrations in blood serum of fish caught in the mouth of the Zavetinka R. showed that the hormone level barely differed from that in the fish from the Tym' R., caught near the spawning grounds, and was 12.9±4.0 ng/mL in females in the IV stage of maturity (n=8), 23.3±4.2 ng/mL in females in the V stage of maturity (n=27), and 3.4±0.4 ng/mL in males in the V stage of maturity (n=35).

Thus, the completion of the process of vitellogenesis and maturation of the gonads in females with a short period of river migration occurs at sea, and not in freshwater conditions, as in fish migrating into the Tym' R.; the hormonal characteristics are governed primarily by the condition of the gonads, and not by the ecological conditions in the period preceding maturation. The results obtained are discussed in connection with the peculiarities of hormonal regulation of the reproductive function in salmonid fishes.

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INTRAPOPULATION STRUCTURE OF ONCORHYNCHUS KETA IN THE RIVER YAMA

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The fundamentals of the population genetics of Pacific salmon /28* were established in the works of Altukhov **et. al.** (1970, 1975, 1980; Altukhov, Rychkov, 1970; Altukhov, 1973, 1974, 1983). In the process of these investigations, heterogeneity was found for the first time in the examination of the chum populations of Sakhalin rivers, where its stocks were replaced with the help of fish hatcheries. The chum of the Northeastern USSR reproduces by natural means, so that the population structure is not disturbed by artificial propagation.

Since 1981, a long-term program of study of the population structure of the chum of this region, including that of the Yama River (coast of Sea of Okhotsk), has been under way. Methods of biochemical genetics have been used to study the frequency distribution of genes encoding LDH, MDH, ME, 6-PHD, Est. D, AAT, and observations have been made of the dynamics of the run. Two peaks of the spawning migration have been detected in the Yama River. As a result of data obtained in 1982, intrapopulation heterogeneity has been found in a number of enzyme systems, giving rise to the assumption that the chum of the Yama R. is differentiated in time and space. In order to test this hypothesis, in 1984 samples of muscles were taken from chum spawners differing in time of spawning run and distributed in spawning grounds of different types. Comparison of these samples also showed their genetic heterogeneity. More detailed studies of

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the genetic structure of the chum population of the Yama River were done in 1986 and 1987. Samples were taken throughout the spawning run at 8-10 day intervals. Analysis of the frequency of the genes which encode certain enzyme systems and the values obtained indicate a high level of heterogeneity within the chum populations of the Yama R.

While the heterogeneity between samples held as the data accumulated, the population as a whole is characterized by stable summary frequencies of alleles. This stability is not disturbed after 5-8 samples have been investigated. It is obvious that the genetic heterogeneity is maintained due to a differential reproduction, fluctuating over the years, of the particular structural components of the entire chum stock of the Yama R. in spawning grounds of different types. However, these fluctuations /29
do not change the overall genetic characteristics of the entire population structure, which remain stable in time.

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THE USE OF THE SALT TEST FOR ASSESSMENT OF SMOLTIFICATION OF JUVENILE BALTIC SALMON

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In the transition to salt water, the salmon fry exhibit the development of hypoosmotic ionic regulation - the ability to actively eliminate excess salts from the organism. /29*

In order to evaluate the development of osmotic adaptation in hatchery propagation of Baltic salmon, a series of experiments was arranged using the so-called "salt test". Observations were done of yearlings. two-year-olds and second-year Baltic salmon at the "Tome" fish hatchery (basin of Gulf of Riga, Daugava R.) from March until July 1987. The experimental fry (15 specimens each) were maintained in aerated aquariums in water with a salinity of 25‰ for a day, and the waste of fish was noted. Blood samples were taken from 3-5 live specimens before the start of the experiment (control) and after 4, 10 and 24 h maintenance. The Na^+ concentration in the blood plasma was determined on an atomic-absorption spectrophotometer. In all, there were 10 experiments. The yearlings had a size of 11.6 to 12.2 cm and a mass of from 17.3 to 19.1 g, two-year-olds 16.6 to 17.4 cm and

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43.9 to 56.8 g, respectively.

In March, the second and third year salmon, transferred to salt water, showed a stable increase in blood plasma Na+ from 160 to 212 mmoles/L after 24 h. A similar picture was noted in April, indicating the inability of the salmon to maintain blood plasma salt balance. A mortality of yearlings of 50% in March and 36% in April was noted in salt tests.

In subsequent tests at the start of May, in the course of the first 10 hours, in the yearlings and two-year-olds the Na+ content increased on average to 121% of the initial (control) indices, after which, as a result of osmoregulation, it began to decline and by the end of the day was only 110%. Mortality of fry was not observed. At the end of May in the salt test, the Na+ content initially rose on average to 125%, but at the end of the test, was restored to 121% of the initial concentration. In addition, a /30
mortality of both second- and third-year juveniles of 25% on average was observed in the latter tests.

A salt test of a wild downstream-migrant salmon juvenile, caught in May at the mouth of the Salatsa R., confirmed its high hypoosomoregulatory abilities. After a brief increase, blood plasma concentration fell to its initial values - 160-165 mmole/L.

Hatchery yearlings, kept at the hatchery until two-years of age, in July had an average size of 15.6 cm and mass 39.7 g. The salt test showed that they had completely lost salt-resistance: the blood plasma Na+ concentration rose to 240 mmole/L in the course of 18 h, after which all the fish died.

In the basin of the Gulf of Riga, in conditions of hatchery culture, the Baltic salmon juvenile achieves its maximal osmoregulatory capacity in the smolt (downstream-migrant) stage at the start of May for a short time. This is apparently the optimal time for the release of hatchery fry in the lower reaches of rivers.

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VIABILITY OF EMBRYOS OF DONALDSON'S TROUT AND THEIR ABILITY TO WITHSTAND MECHANICAL STIMULI

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Study of the viability of the eggs and juveniles of salmonid fishes is required in order to create optimal conditions of artificial reproduction, as well as for the selection of the most viable progeny for breeding purposes. From the theoretical point of view, lithophilous fish are of interest because of the peculiarities of their reproduction and development. In the spawning redd, the salmon eggs are acted upon by a constant load in the form of the weight of stones and sand, but the embryos do not experience dynamic loads - rolling, jerks, etc. Consequently, throughout the long embryonal period, the embryos are not subject to natural selection, directed at the rejection of progeny which is not resistant to dynamic effects. In this connection, the application of a dosed mechanical effect (vibration) offers the possibility of establishing by experimental means which processes in the embryogenesis of salmonid fishes are the most vulnerable to dynamic effects and consequently are specifically adapted to development in immobile state. /30*

The investigations were done in 1986-1987 in Kazakhstan, at the Turgensk trout farm. Donaldson's trout obtained in Japan in 1982 in the form of fertilized eggs and cultivated at the farm to sexually mature condition, was used in the experiments. Materials on rainbow trout of the Turgensk population was taken for comparison. /31

The female Donaldson's trout matured at the age of 4-5 years. The mortality of the eggs during embryonal development was 6.0%

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in the experiment. The fertilization of the eggs was 92.7%. For rainbow trout of the Turgensk population, the same indices were 9.0% and 85.7% respectively.

Study of the resistance of the embryos to vibration, done at different stages of embryogenesis, revealed a maximal sensitivity of the embryos to dynamic effects during the epiboly of the blastoderm. This is due to the presence of an enormous reserve of vitellus and to peculiarities of its overgrowth by the blastoderm. Experiments with the eggs of rainbow trout of different sizes showed that embryos in large eggs are the most vulnerable to vibration.

Thus, the absence of dynamic loads during the embryogenesis of salmonid fishes allows the embryos to develop with an enormous reserve of vitellus in the thin-walled vitelline sac, which would be difficult in a moving water medium.

Investigation of unfertilized eggs of Donaldson's trout made it possible to establish the dynamics of their mortality and showed the absence of a connection between increase in mortality and sensitivity to dynamic effects.

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GENETIC PRINCIPLES OF AGE DIFFERENTIATION IN O. NERKA OF LAKE KURILSKOE

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The regularities of age differentiation in sockeye are still /48* not clear, although they have long interested investigators. Some investigators consider the genetic nature of this character in the sockeye to be obvious (Foerster, 1966; Ricker, 1972; Krogius, 1978; Konovalov, 1980), although attempts to obtain direct evidence have met with no success. This is because the works which have dealt with this problem have compared portions of age groups which have been selected by final age of individuals. This approach precluded establishing the genetic dependence of variation in the rate of sexual maturation, since the duration of the freshwater period does not depend on the rate of sexual maturation.

In the present paper, variability in the duration of the marine period of the life of the sockeye is considered independently of the freshwater period. Data on the age structure of 40 generations of Lake Kurilskoe sockeye, kindly made available by M.M. Selifonov, served as the material.

The nature of distributions by duration of the marine period in samples of Lake Kurilskoe sockeye migrating for spawning, allow us to propose a single-locus autosomal two-allele hypothetical system of inheritance of the gene of the rate of sexual maturation (G gene), in which fishes with 3 marine years should be considered homozygotes by the slow maturation allele, those with 1 marine year - homozygotes by the rapid maturation allele and those with

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2 marine years, heterozygotes. Thus, genetic polymorphism in the rate of sexual maturation should be manifest phenotypically in variability in marine period duration.

Distributions of marine period duration in samples of adult fish migrating for spawning in 1981-86 corresponded closely to those theoretically expected by the Hardy-Weinberg law. On the basis of this fact, we calculated the G gene frequencies in /49 the parental part of the stock and in the generations born in the spawning of these adults, taking into account shore and sea catches. Correlation analysis showed the existence of a reliable connection between the G gene frequency in spawners and progeny ($P<0.05$), which proves the genetic dependence of polymorphism in the rate of sexual maturation. The average long-term frequency of the gene in the parental part of the stock (0.761), was close to that in the progeny (0.762), but the genetic variance in the parental generations was 1.5 times greater than that in the filial generations. Analysis of the long-term dynamics of gene frequency revealed a cyclical alternation of equilibrium periods (of 12 years each) when the correlation of G gene frequencies in spawners and progeny was high ($r=0.68$, $P<0.01$), with periods of disturbed equilibrium (3-4 years each), when there was no correlation. It was found that selection in favor of heterozygotes is characteristic of the equilibrium periods, while disturbances in equilibrium are associated with change in the direction of selection. In the period from the end of the 40s to the end of the 70s, a reduction was observed in the frequency of the slow maturation allele, which reflects the existence in this period of selection in favor of early maturing individuals, apparently connected with the selectivity of the fishery. The frequency of the slow-maturation allele subsequently began to increase

Based on these results, a method of predicting the expected distribution of marine period duration on the basis of determining the G gene frequency in the parent generation, taking into consideration the factors which influence it in the spawning period, has been proposed.

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SPATIAL AND TEMPORAL GENETIC STRUCTURE IN THE POPULATION SYSTEM OF O. NERKA IN LAKE KURILSKOE (KAMCHATKA)

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Using the method of electrophoresis in polyacrylamide gel, the /49*
frequencies of polymorphous Ldh - B_1 and Pgm loci were determined in sequential samples of adults migrating for spawning (1450 spec.) and juveniles migrating out to sea (1370 spec.) in 1984-86. Spawning local groupings (subpopulations) were investigated from July /50
to November 1985-86. In all 31 samples were studied which were caught on littoral and river spawning grounds.

In order to determine the nature of the population structures, it was first necessary to resolve the question as to the existence of seasonal races. In connection with the fact that the spawning run into Lake Kurilskoe lasts continuously from the beginning of June until the end of September, having a peak at the start of August, some investigators consider that a single, summer race spawns in Lake Kurilskoe (Krogius, 1983). This assertion is doubtful, since spawning in the tributaries of Lake Kurilskoe begins in the middle and sometimes even at the beginning of July, which is not characteristic of the summer (late) race.

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Study of the dynamics of the Ldh-B1 gene frequencies in samples from the spawning run of adults showed a reliable increase in the frequency of the Ldh-B_1 (slow) allele from the June (0.721-0.735) to the September (0.882-0.900) samples. A similar picture was observed in studying the downstream migrant juveniles. The early-migrating juveniles (beginning of June) are characterized by lower frequencies of the Ldh-B_1 allele (0.758-0.769) by comparison with the late migrating ones (0.8160-0.882). The dynamics of the genetic and biological indices in subpopulations during the course of the spawning season confirmed this conclusion. The differences between sample series, grouped in accordance with the nature of spawning grounds and the time of spawning, proved to be reliable. We may thus consider it proved that there exist in Lake Kurilskoe 3 seasonal-ecological forms - the early river, late river and late littoral forms and that considerable reproductive isolation exists between the first and the last land determines a high level of differentiation in the Ldh-B_1 locus ($t = 2.7$, $P<0.01$, Table 1). In all its characters, the late river form exhibits intermediate values, which may indicate the hybrid, to some extent, nature of this form. The exchange of genes between this form and the early river and summer littoral forms can apparently be considerable.

The general level of genetic heterogeneity, as estimated from samples from spawning grounds, proved to be considerably lower than has been noted for the sockeye populations of Lake Azabach'ee (Altukhov et al., 1983) and Lake Nachikinskoe (Varnavskaya, 1984). The variability in the Ldh-B_1 gene frequencies is of the nature of a temporal cline.

/51

TABLE I

GENOTYPIC DISTRIBUTIONS AND FREQUENCIES OF Ldh-B_1-ALLELE IN TOTAL SAMPLES FROM SPAWNING GROUNDS OF SEASONAL-ECOLOGICAL FORMS OF O. NERKA OF LAKE KURILSKOE

Форма 1	Объем выборки 2	Генотипические распределения 3			Частота Ldh-B_1-аллеля 4
4 весенняя речная	226	139(137,1)	74(77,8)	13(11,1)	0,779±0,019
5 летняя речная	243	154(154,6)	69(67,9)	6(7,5)	0,820±0,018
7 летняя литораль-ная	242	178(175,2)	56(61,4)	8(5,6)	0,851±0,016

Key to Table 1

1 - form; 2 sample volume; 3 - genotypic distributions; 4 frequency of Ldh-B_1-allele; 4_1 - spring river form; 5 - summer river form; 7 - summer littoral form.

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ANALYSIS OF THE RNA/DNA INDEX IN SALMONID FISHES DURING THE CHANGE IN HABITAT AND ITS CONNECTION WITH THE RATE OF GROWTH OF THE FISHES

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Evaluation of the rate of growth of salmonid fishes in the coastal period of life on the basis of the traditional method of catching of fish at certain time intervals and analysis of the growth increment is very approximate due to the constant emigration and immigration of the fishes. /53*

The high sensitivity of the RNA/DNA index to different growth rates in salmonid fishes (Thorpe et al., 1982; Wilder, Stanley, 1983; Nakano et al., 1985) was a basis for conducting an evaluation of this index in juveniles of the different exterior types that characterize the process of smoltification: parr (P), presmolt (PS), smolt (S). We studied the fry of the silver salmon (252 specimens), as well as silver salmon, chum salmon and humpback salmon adults (72 specimens). A weighed sample of muscle tissue (50 mg) was placed in 2 mL of 0.5 M KOH, homogenized and 0.01 mL of solution was sampled to determine protein (Lowry et al., 2955). The solution was then incubated in a water bath (10 min., 100°C), after which 1.4 mL of concentrated $HClO_4$ was added to the alkaline

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extract and after precipitation of the $KClO_4$ the sample was centrifuged (10 min., 5000 rev/min). Total RNA was determined in the supernatant fluid (photometry of samples on the SF-46 at wave length 260 nm). To the precipitate was added 2 mL of 0.5 M $HClO_4$ and the sample was incubated for 20 min in a water bath at 100° C. After cooling and centrifuging, DNA in solution was determined at 260 nm.

The RNA/DNA index in S, caught at different times in Avachinskaya Bay, was in the range 2.04 ± 0.04 - 2.64 ± 0.15, which is reliably ($P<0.01$) higher than in PS and P, for which the same values were 1.82 ± 0.06 and 1.55 ± 0.07, respectively. The frequency of distribution of the RNA/DNA index values in groups of fish belonging to different exterior types makes it possible to assess the transgression in this index. It was on the order of 30% between S and P, and also S and PS. It is therefore not advisable to assume any sort of threshold values of the index in order to differentiate on this basis the analyzed juveniles into S and PS. The error in fish classification will be rather high, although still lower than in the analysis of hematological indices or in using the Na+, K+ and ATPase test.

Prolonged starvation of silver salmon smolts depressed growth, /54 which was reflected not only in the value of the relative daily increment (G), but also in the RNA/DNA index, which was reliable lowered in the first ten days to the level of 1.50-1.73, which is typical of salmonid P, PS and adults during the anadromous migration, when the fish cease to feed. In the next 10 days of starving, the index fell to 1.17 ± 0.04. The value of G, which in silver salmon juveniles in Avachinskaya Bay according to our data is 1.4% per day on average, began to take on a negative value after 20 days of starvation (-0.10%).

The RNA/DNA index is deserving of the closest attention in the evaluation of the quality of salmonid juveniles during the habitat change, taking into account the procedural simplicity of the analysis and considering that this index indirectly reflects the most essential feature of the smoltification process - the differences in the rate of growth in sea water in fishes of different physiological condition.

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VARIABILITY IN GENETIC POPULATION STRUCTURE OF CULTURED JUVENILE BALTIC SALMON

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In the population of the Baltic salmon of the Daugava R., the /54*
allozymes of the malicenzyme (ME) are polymorphous. The three variants discovered by the method of electrophoresis in polyacrylamide gel correspond to the variants described for the Neva and Narva populations: AS, AD, VD (Slyn'ko et al., 1980, 1981).

We have analyzed adults stocked for the "Tome" hatchery and juveniles in the process of hatchery cultivation from larva to release as a yearling.

The genotypical frequencies of ME in adults and larvae, obtained from these adults, correspond to each other. Subsequently, in the process of hatchery cultivation, the genetic structure changes. The variability can be characterized by the frequencies of the heterozygotes (p AD), since the homozygotous VD variant is rare (p VD = 0 - 0.6). Towards the middle of the summer, first an increase and then a decrease (or vice versa) is observed in the frequency of the heterozygotes. The differences are statistically reliable. As a result, by the time of release, the genetic structure of the yearlings approaches that typical of adults.

It is assumed that this variability in the frequency of the /55
heterozygotous genotypes is due to change in the direction of operation of selection in time. The different nature of variability in different years (increase or decrease in the frequency of heterozygotes) is probably determined by the specific conditions of the particular year.

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Год сбора икры 1		Производители 2	Молодь 3		
			Май 4 Личинки	Июль 5 Мальки	Апрель 6 Годовики
1982	р АД 7	-	-	0,33	0,23
	к-во 8	-	-	209	387
1983	р АД 7	0,09	0,10	0,05	0,09
	к-во 8	101	215	227	228
1984	р АД 7	0,21	0,24	0,35	0,21
	к-во 8	123	256	256	512
1985	р АД 7	0,23	0,21	0,32	0,20
	к-во 8	149	288	288	259

Key to table: 1 - year eggs collected; 2 - adults; 3 - juveniles; 4 - May larvae; 5 - July fingerlings; 6 - April yearlings; 7 - pAD; 8 - number.

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GENETIC STUDIES ON SALMONIDS

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Genetic studies on salmonids have been done more intensively /57* than on other fishes. The salmonids were one of the first fishes on whose karyotypes reliable information was obtained. Following the discovery of isoenzymes, the genetics of the natural populations of these fishes began to develop particularly intensively. Although the development of the comparative and evolutionary genetics of the salmonids proceeded somewhat more slowly than the development of population genetics, even so even this field of genetic has accumulated vast data and has made a number of important generalizations of both major general biological significance as well as of a more particular nature, relating to the basic trends and mechanisms in the evolution of this important group of fishes.

The karyotypes of the salmonids have received the greatest amount of study. At this time, some new details on the peculiarities of chromosomal morphology in certain species, and the distribution of accessory chromosomes can be added or refined, additional cases of the existence of heteromorphous sex chromosomes have been described, etc. However, enough study of the karyotypes has been done that we may no longer expect our concepts in this field to change seriously and the evolutionary paths of all the subfamilies, genera and the great majority of the species are clear. It is likely that the last vexing obscurities with respect to the karyotypes of certain species will disappear in the next few years, although this will still not affect the whole picture, since they relate for the most part to endemic forms and forms with a small range.

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In recent years, there has been a serious increase in the number of studies on the comparative biochemical genetics of the salmonids, although the amount of study that has been devoted to many genera and species is extremely uneven. The Pacific salmon **Oncrorhyncus** and the Pacific trout **Parasalmo** have been studied most fully, **Salmo** and **Salvelinus** have been studied somewhat less, while **Brachymystax, Hucho** and **Parahucho** have been studied very poorly. Until recently, studies on the comparative biochemical genetics of the coregonid subfamily lagged considerably behind those of the salmonid subfamily. However, this situation has now begun to be corrected and in the near future the study of these groups will already be on the same level. The study of the thymallids continues to lag far behind.

The aggregate of data so far accumulated on the comparative karyology and comparative biochemical genetics urgently requires /58
the re-examination of a number of concepts about the system of the salmonid subfamily, although with respect to the coregnoid subfamily these new materials on the whole have confirmed the idea that it is composed of three genera, the genus **Prosopium** being the most isolated. The greater closeness of **Salmoninae** and **Coregoninae** to each other, than to **Thymallinae**, has become still clearer. Findings of biochemical genetics are usually used to establish genetic distances between species (most often after Nei), although they also allow of interpretation in the context of the concepts traditional to systematists, based on the weighting of characters. This approach is especially interesting for the comparison of supraspecies taxa.

Studies on the population genetics of salmonids have developed particularly intensively in recent years, although this development has included a small number of species. The chum salmon has been studied intensively, the sockeye and pink salmon somewhat less so. Studies of the masu and coho have begun. A notable phenomenon are the studies on the genogeography and population structure of the Pacific trouts (**Parasalmo**). Information obtained recently on the exceptionally low genetic variability of some salmonids, data on the population structure of the true trouts (**Salmo trutta**), as well as the first works laying the basis of the population genetics of the coregonids, are of great interest.

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GENETIC POPULATION STRUCTURE OF O. KETA

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Studies of the genetic population structure of the chum /58*
salmon, begun by the works of Yu. P. Altukhov (1973), have developed rather intensively. Thanks to the efforts of a number of investigators (Altukhov, 1974, 1983; Altukhov **et al.**, 1980; Okazaki, 1979, 1980, 1981; Salmenkova **et al.**, 1985; Viktorovskii **et al.**, 1985), the chum has become the most well studied salmonid species. Although the approach of foreign and Soviet works has differed substantially, a vast and comparable body of data has already been accumulated on the greater part of the range of this species. At present data are entirely lacking only on the chum of Primor'e, the basin of the eastern part of Shelikhov Bay (Penzhina R.) and the basin of the extreme western part of the Sea of Okhotsk (Tugur, Uda). Although the chum of the rivers of America and Japan /59
have been studied in great detail, there, unfortunately, with rare exceptions, data are lacking on the distribution of gene frequencies for time of spawning run and long-term data.

By contrast, in Soviet works, the populations of a number of rivers have been studied (the Taui, Yama, Avacha, Kamchatka and Anadyr' rivers), and extensive data have been accumulated on the change in the distribution of gene frequencies in the course of the spawning run for some of them (Yama, Pakhacha rivers). In addition, the level of genetic variability has been compared with the size-age makeup of populations. This considerably improves

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the reliability of data on the genogeography of the chum of the Soviet Far East.

Despite the fact that a not quite identical set of loci has been used in the works of Soviet and foreign investigators, the data obtained allow us to evaluate both the level of genetic variability of particular local stocks, as well as to note the general outlines of the population organization of this species.

The level of genetic variability in different populations of the chum varies quite markedly. The level of genetic variability is particularly low in the chum reproducing on the Pacific coast of America (not including the Yukon). On the Asian coast of the Pacific, the chum of the Amur R. has the least genetic variability. The chum of all the studied populations of the rivers of the Okhotsk basin, the eastern coast of Kamchatka, and also Japan, has a relatively high level of genetic variability.

Unfortunately, the materials of foreign investigators do not allow us to judge the level of genetic heterogeneity of the populations which they have studied, since they have been limited to single samples. In those rivers of the Soviet Far East, where long-term data have been accumulated at different times of the spawning run, a complicated picture has emerged. The genetic heterogeneity of the populations has been shown for the chum of a number of rivers in the Okhotsk basin and Kamchatka. At the same time, the local chum stock of the Anadyr'R., which has enormous abundance and range, turned out to be exceptionally homogenous. The results obtained suggest that intrapopulation structures are not a universal and constant feature of the species. They develop in the process of mastery of its range by the species and reflect the specific intrapopulation peculiarities that arise in different ways and at different
historical intervals. The entire complex of historically /60
determined conditions in which the species assimilates the territory of its range participates in the establishment of these peculiarities of the population structure, which can develop on different genetic bases.

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STUDIES ON THE GENETIC STRUCTURE OF SOME POPULATIONS OF KAMCHATKAN O. GORBUSCHA

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This work presents the results of the study of the population genetics of the Kamchatkan pink salmon over a number of years (1982-1986). /65*

Pink salmon adults, caught in certain spawning waters on the eastern and western coasts of Kamchatka were studied. The method of electrophoresis in polyacrylamide gel with subsequent specific staining of the following polymorphous enzyme systems: sMdh, Pgm, ₄-Gpd and 6-Pgd, was used to determine genetic variability. The results obtained were analyzed statistically using a pheno- and genotype frequency test for sample heterogeneity.

Comparison of the genetic characteristics of the pink salmon populations of even and odd years showed that the pink salmon samples in the even years (1984, 1986) differed substantially from those of the odd years (1983, 1985) in the frequency of phenotypes and alleles of all the loci which we studied (Table).

Our findings on the genetic differences between the pink salmon populations of even and odd years are in agreement with available published data (Salmenkova et al., 1981).

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Год	Число рыб	Частоты фенотипов sMdh -3,4		Частоты аллелей		
		без "быстрых" аллозимов	без "медленных" аллозимов	Pgm-1^B	α-Gpd^B	6-Pgd^A
		НЕЧЕТНЫЕ ГОДЫ				
1983	712	.912	.895	.912	.907	.979
1985	420	.955	.905	.925	.954	.924
		ЧЕТНЫЕ ГОДЫ				
1984	1072	.991	.969	.998	.917	.855
1986	255	.976	.965	.998	.929	.831

Key to table:
1 - year; 2 - number of fishes; 3 - frequency of sMdh-3,4 phenotypes; 4 - without "fast" allozymes; 5 - without "slow" allozymes: 6 - frequency of alleles; 7 - odd years; 8 - even years.

The genetic difference of the Kamchatka pink salmon from the stocks in other parts of its vast range has been shown. Data have been obtained on the interpopulation differences of the Kamchatka /66
pink salmon. Both the populations in different regions of the peninsula, as well as the subpopulations in the basin of the same river, differ genetically from each other. Genetic differentiation of pink salmon adults by time of spawning run has also been found.

On the basis of the results of our own studies and the available published data, the causes and patterns of the formation of the complex population structure of the pink salmon are discussed.

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POPULATION STRUCTURE OF O. NERKA IN LAKE AZABACHE (KAMCHATKA)

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The population biology of the sockeye in Lake Azabache has been /68* studied in greater detail than in other localities. In particular, the space and time makeup of the Azabache sockeye stock, which is made up of more than 30 subisolates and two seasonal races - spring and summer, is well known (Konovalov , 1980). However, the interrelations of these groupings, that is, the population structure of the stock, has until now remained inadequately studied.

The population structure of the Lake Azabache sockeye was studied on the basis of an original methodology, developed previously (Glubokovskii, Zhivotovskii, 1985, 1986). In 1986, 16 samples were taken of subisolates of the spring and summer race and 8 samples from the Bushuika R., where more than half of the Azabache sockeye stock reproduces. In 1987, the structure of the summer sockeye was refined, having taken 20 samples (6 of them from the Bushuika R.). In each of the 2064 specimens, 18 exterior characters were measured by I.F. Pravdin's modified measurement system and the genotypes of the polymorphous LDH and PHM enzymes were registered. The primary data were processed on an ES 1060 computer using cluster, factor and discriminant analysis apparatus.

The study showed that the Azabache sockeye stock breaks down clearly into two clusters of subisolates, one of which belongs to the spring and the other to the summer race. In addition, a group

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of samples is quite clearly isolated from the summer sockeye and represents a fall fish which enters the Bushuika R. at the end of August - beginning of September. We should note that these differences are more pronounced for the complex of morphological characters than for the polymorphous enzymes. Judging by the morphological features, in the spring sockeye, the closely situated Arishkin and Kultuchnaya, and to a somewhat lesser extent, the Atkhl, Vtoraya Timofeevskaya chasha and Ozerko river subisolates are the most closely related. In the summer sockeye, we can distinguish two groups of closely connected lacustrine subisolates: 1) the Zemlyanka-Lotnaya, Lotnaya-Zemlyanka and Lotnaya-Rybovodnaya; 2) the Snovidovskaya, Kultuchnaya,and Arishkin, to which the Kultuchanaya-Lamutka and Rybovodnaya adjoin, and also the summer sockeye from the Bushuika R.

The overlap of subsets in discriminant analysis, with some assumptions, can be used to evaluate the coefficient of migration between subisolates. These estimates for the spring sockeye fluctuate from 0 to 18%, average 4.7% and for the summer sockeye from 0 to 19%, average 5%. The migration coefficient estimates by this method typically were very close to the estimates of Il'in et al. (1983) (from 0 to 16%, average about 4%), obtained by tagging. The coefficient of migration between the subisolates of the spring and summer sockeye according to our estimates fluctuates from 0 to 1% and on average amounts to only 0.04% /69

Thus, at least two independent sockeye populations, spring and summer, reproduces in Lake Azabache. Each of them consists of a system of interacting subisolates which make up their subpopulation structure. The population status of the fall sockeye that enters the Bushuika R. requires clarification. These results must be taken into account in the development of studies in the field of population genetics and the theory of population dynamics, and also in studying the problems of predicting spawning runs and the efficient exploitation of the Azabache sockeye.

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POPULATION STRUCTURE OF O. GORBUSCHA

By M.K. Glubokovskii, L.A. Zhivotovskii, R.M. Viktorovskii, K.I. Afanas'ev, L.N. Ermolenko, V.V. Efremov, A.I. Karpenko, V.G. Kovalev, A.N. Makoedov, T.V. Malinina, S.P. Pustovoit and G.A. Rubtsova

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Knowledge of the population structure of fishes is the /69*
essential scientific basis for the rational utilization of fish stocks and forecasting their abundance. In recent years (1979-1986), a large body of data has been accumulated on the genetic and morphological peculiarities of the Asian pink salmon on its range from Primor'e and the Southern Kurils to the Chukchi Peninsula. These findings, together with the published information on the American pink salmon, provide sufficient grounds for judging the peculiarities of the population organization of this species. The views of investigators on the population organization of the species in the pink salmon differ quite markedly. The pink salmon population structure models in question can be divided into three groups: 1) the "local stocks model", on the basis of which the pink /70
salmon has been differentiated into a number of mutually isolated self-reproducing groupings, which are confined to spawning areas and even to particular spawning rivers or to certain marine foraging areas; 2) the "intermingling stocks model", according to which the pink salmon stocks regularly exchange a large number of migrants, that is, are essentially panmictic; 3) the "fluctuating stocks model", according to which the boundaries,

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number and abundance of local pink salmon stocks are not constant, but rather subject to periodic changes which are governed by regular, sometimes substantial, fluctuations in the migration flows between local stocks.

Cluster analysis of samples from different regions with respect to quantitative characters and gene markers, summary data on tagging results at salmon hatcheries in Sakhalin oblast and published data on pink salmon homing and straying suggest that the fluctuating stocks model is the most adequate one. Migrations play a large role in the formation of the population structure of the pink salmon. For example, in the Sakhalin-Kuril Basin, the average exchange between regions is more than 20-30%, fluctuating from total absence of migration between some regions in some years to more than 60% exchange in other years. Another important factor in the formation of the genetic structure of pink salmon populations is differentiated (by regions) selection. We do not consider drift to be an important factor in the population genetics dynamics of the pink salmon.

The fluctuating stocks model by no means presumes panmixia: fluctuations in the migration flows can occur asynchronously in different regions of the range. Then in some portions of the range the population structure will correspond temporarily to the local stocks model, while in others it may answer to different variants of the model with a considerable exchange of individuals. The situation can reverse itself in time. The most important parameter of the fluctuating stocks model, besides migration intensity, is the periodicity of change in migration flows. The species population structure in the pink salmon appears to us to be two-level. The first level comprises the generations of even and odd years, each of which is a self-reproducing population. The second level represents a system of fluctuating stocks (subpopulations), which mutually interact.

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REGULATION OF THE RELATIVE DURATION OF EMBRYOGENY IN THE PACIFIC SALMON OF THE GENUS ONCORHYNCUS

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The opinion has developed in the literature that in /72*
different fish species, the act of hatching of embryos from the egg shells is not fixed at a determined morphological stage and can shift to earlier or later stages depending on external conditions (Buznikov, 1957; Gerside, 1959; Pavlov, Fridrikh, 1981). The elaboration of methods of determining the relative duration of the embryonal development stage (Detlaf and Detlaf, 1960; Gorodilov, 1980), which can be considered an indicator of the biological age of the embryo, makes it possible to calculate this shift /73
quantitatively. An increase in temperature usually stimulates the emergence of the larvae at morphologically earlier stages (Gorodilov, 1983, 1985). The salmon of the genus **Oncorhyncus**, in which this process is stimulated by a drop in environmental temperature, are an exception (Gorodilov, Svimonishvili, 1981). This work presents the results of observations that confirm the latter statement in two salmon species (**Oncorhynchus gorbuscha** and **O. keta**) and which reveal the mechanism which apparently underlies this phenomenon.

The relative duration of the period from fertilization of eggs to mass (50%) emergence of larvae in different temperature conditions was determined in the course of development in chum and pink salmon. The measure of the relative duration of stages of

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embryogenesis was the time (t_s) of formation at a given temperature of a single pair of somites in the period of segmentation of the anlage of the embryo musculature (Gorodilov, 1980). It has been found that the relative duration of the incubation period from fertilization of the eggs to the mass hatching of larvae at different constant temperatures in the range from 1.0 to 11.5°C in both chum and pink salmon is equivalent to 330-470 t_s, and that the duration of this period increased with increase in incubation temperature. This can also be seen from data on absolute duration of incubation period which in chum for example at a temperature of 5.0° was 108 days, at 8.4° 70 and at 11.5° 55 days; however, if the ratio of high and low temperature development rates had remained the same in late stages as in the early ones, then the duration of embryogenesis in the same conditions would have been 103, 60 and 38 days, respectively.

It was also found that the phenomenon which we detected of slowing down in the development of chum and pink salmon embryos at high temperatures correlates with a delay at high temperatures in the maturation of two generations of erythrocytes - of the embryonal and definitive types. The succession of erythrocyte generations is delayed at high temperatures: thus, polychromatophilous erythrocytes of the definitive type appear at 5.0 and 8.4° before the hatching of embryos (earlier at 5.0°), while at 11.5°, they appear only after hatching. At 8.4 and 11.5°, the erythrocytes of the embryonal type remain longer in circulation. The time of their mass destruction can be determined from the change in the number of haemosiderin-containing macrophages, and this time is also delayed at high temperature.

One possible cause of retarded embryonal development at late stages is a lowered metabolic rate, since the less mature erythrocytes contain a smaller amount of haemoglobin. Since the /74
latter determines a low gas exchange rate, one might very likely suspect a link between the delayed maturation of the erythrocytes and the retarded development of the whole embryo at high temperatures. We can understand the biological meaning of this phenomenon if we regard it as some sort of biological adaptation to the seasonal cycles of nature that has developed in connection with the reproductive peculiarities of Pacific salmon. It is particularly manifest in abnormally warm falls, preventing accelerated development and regulating the consumption of vitelline nourishment, the supply of which must last 8-9 months.

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CYTOGENETIC ASSESSMENT OF VIABILITY OF RAINBOW TROUT PROGENY

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Karyological analysis has been done on Donaldson's trout and /74* local rainbow trout embryos ("Banga" fishing collective farm, Latvian SSR).

The embryos fell into three basic groups by level of chromosomal disturbances: I - embryos with low level of cytogenetic disturbances (up to 10% aberrant cells per embryo); II - embryos with average level of disturbances (up to 25% aberrant cells); III - embryos with high level of disturbances (more than 25%). Obviously, embryos with a high level of disturbances are eliminated at early stages of embryogenesis. Presumably, embryos with average, and possibly low level of disturbances have a low viability and die at critical stages in ontogenesis or in the case of adverse environmental conditions.

The Table presents the results of the karyological analysis of mass crossings of trout done in March 1987.

The most widespread cytoplasmic disturbances in the /75 embryogenesis of Donaldson's trout are mass retardation of chromosomes in anaphase, chromosomal bridges, haploid and aneuploid cells and pyknosis of chromosomes. Haploid cells, pyknoses and cytoplasmic disturbances are often found in the embryogenesis of local trout. In all samples, some of the eggs were found to be anuclear. These included both unfertilized and fertilized eggs which for genetic causes had terminated their development in the first few days. The results of karyological analysis make it possible to determine the natural mortality due to genetic causes,

*The numbers in the right-hand margin indicate the corresponding pages in the original. - Transl.

TABLE

Форма 1	Кол-во эмбрионов 2	Эмбрионы, % 3				
		Типы нарушений 4			Цитоплазматические нарушения 5	Без ядер 6
		I	II	III		
7 Местная форель	143	2,9	4,2	6,2	7,0	18,8
8 Форель Дональдсона	100	11,0	4,0	16,0	3,0	24,0

Key to table:
1 - form ; 2 - number of embryos; 3 - embryos, %; 4 - types of disturbances; 5 - cytoplasmic disturbances; 6 - anuclear; 7 - local trout; 8 - Donaldson's trout.

over incubation time, which cannot be lowered by biotechnical measures at salmon hatcheries. Based on the number of embryos with different disturbances, Donaldson's trout should have the greatest waste of eggs amounting to at least 42%; the waste is lower, 32%, in local trout. Obviously, at least 15% of Donaldson's trout embryos have low viability and these individuals can be eliminated either by adverse conditions or at critical stages of ontogenesis. In local trout, the presumed waste at critical stages of development is half as much.

Data on the presumed waste of fertilized eggs for genetic reasons are required in order to plan egg procurements and also to determine the permissible minimal waste norms in the incubation period. Karyological analysis of early embryogenesis should be done at all trout farms; this method is quite simple, and does not require expensive reagents and equipment.

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RESULTS OF INCUBATING OF EGGS OF COREGONUS PELED, OBTAINED IN WATERS WITH HIGH MINERALIZATION

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Sibrybniiproekt

The instability in the volumes of coregonid eggs procured at /101*
the traditional collection sites, which is due to the fluctuation in the spawning run, made it necessary to create our own spawning stocks. Work is being done in Novosibirsk oblast to create peled brood stocks in major fisheries waters with high mineralization (Lake Chany and Lake Ubinskoe). It is mainly two-year-old spawners (average mass 320-400 g), which are used to obtain sexual products. The eggs are incubated at the Novosibirsk fish nursery (the total mineralization of the water in the shop's system is 300-500 mg/L).

In the fall of 1985, 40.4 million eggs were stocked at the Uryumsk fish hatchery (Lake Chany). The total mineralization of the water during the foraging of adults fluctuated from 720 to 1040 mg/L. The fertilization, determined at the small cell morula stage amounted to 45%. In the spring of 1986, 8.1 million larvae (20% of the eggs procured) was obtained from these eggs.

In 1986, eggs were collected at the Ubinsk and Uryumsk fish nurturies (the total mineralization of the water in the summer-fall period is 1300-1550 mg/L and 650-800 mg/L, respectively). /102
Water with a mineralization of 180 mg/L was used in fertilization and removal of mucilage to improve the quality of the eggs. The number of eggs obtained was: at the Ubinsk nursery - 72.9 million, at the Uryumsk nursery 12.0 million. The ratio of normally developing eggs, determined at the small cell morula stage, was: 53% for the Lake Ubinskoe peled and 69% for the Lake Uryum

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peled. In the spring of 1987, 17.4 million larvae were obtained from the "Ubinsk" eggs and 5.7 million larvae from the "Uryumsk" eggs. Observations of embryonal development were done in the winter. Peled eggs procured in the Middle Ob' R. (mineralization of water 150-200 mg/L) were used as a control. The Table presents the results of the observations.

TABLE

Percentage of normally developing embryos from all eggs obtained depending on the mineralization of the body of water in which they were spawned (1986-1987).

Место сбора, минерализация водоема 1	Окт. 2	Нояб. 3	Дек. 4	Янв. 5	Февр. 6	Март 7	Апр 8	Май (выход личинок) 9
Убинский р/п 10 1300-1550 мг/л	-	-	63	37	29	28	27	22
Урюмский р/п 11 650-800 мг/л	-	-	69	63	56	56	55	47
Средняя Обь 12 150-200 мг/л	84	77	76	75	74	74	72	69

Key to Table:
1 - place collected, mineralization of body of water; 2 - October; 3 - November; 4 - December; 5 - January; 6 - February; 7 - March; 8 - April; 9 - May (emergence of larvae); 10 - Ubinsk hatchery 1300-1550 mg/L; 11 - Uryumsk hatchery 650 - 800 mg/L; 12 - Middle Ob' 150 - 200 mg/L.

Thus, the incubation results confirmed the possibility in principle of obtaining larvae from eggs procured in waters with high mineralization (700-1500 mg/L) in the south of Western Siberia. A direct relationship is noted between the mineralization of the body of water and the quality of the eggs, which is in agreement with the findings of other authors. In the fall of 1987 it is planned to perform a series of experiments to study the effect on egg quality of water of different mineralization and pH used in fertilization and removal of mucilage.

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GENETIC VARIABILITY AND DIVERGENCE IN WHITEFISH

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Affinities within the subfamily Coregoninae, the time of /107*
of separation of taxa, the rate and direction of their evolution have until now remained largely controversial. The current, rather contradictory notions of the taxonomic status of the whitefish and their phylogenetic proximity are based primarily on data on morphology and karyology (Shaposhnikova, 1976; Reshetnikov, 1980; Viktorovskii **et al.**, 1983). Studies on the biochemical genetics of the whitefish so far have been few in comparison with similar works on salmonids and for the most part treat certain species of the genus **Coregonus** (Ferguson **et al.**, 1978; Vuorinen, 1981, 1984; Lokshina, 1983; Kartavtsev **et al.**, 1983). In these works, estimates of the degree of genetic closeness of series of species are given. Undoubtedly, data of this kind, taken together with the results of traditional research will help to clarify a number of disputed problems in the phylogeny and evolution of the whitefish.

This paper presents some results of the genetic-biochemical analysis of 9 species of the genus **Coregonus** (**C. autumnalis, C. peled, C. tugun, C. muksun**, Yenisei R.; **C. sardinella, C. lavaretus pidschian, C. nasus** - of the Yenisei, Anadyr' and Chaun rivers; **C. ussuriensis, C. chadary** of the Khor R.), as well as the nelma (**Stenodus leucichthys nelma** - Yenisei and Anadyr' rivers) and the round whitefish (**Prosopium cylindraceum** of the Anadyr R.).

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On the basis of electrophoretic analysis of 20-32 enzyme and nonenzyme loci, estimates of polymorphism and average heterozygosity have been made, and the indices of genetic similarity and difference (Nei, 1972) of the enumerated species of the genus **Coregonus** have been calculated.

In the study whitefish species, the polymorphous locus ratio /108
(P0.99), varies from 0.10 to 0.40, average heterozygosity (H) from 0.01 to 0.08. The omul, tugun, peled and chir are the most isolated within the genus, which is in good agreement with karyological findings (Viktorovskii **et al.**, 1983), and permits us to speak of a more ancient divergence of these species. The highest P (0.30-0.40) and H (0.05-0.08) estimates have been obtained for these species (excluding the chir). Among other whitefish, the cisco [**C. sardinella**] has similar values (P 0.39, H 0.08); the indices for the chir are P 0.12, H 0.03. The Ob whitefish ["pyzhyan"], Ussuri whitefish, muksun, Khadary whitefish and cisco formed a genetically close group. The genetic distances within the group are considerably smaller than between a particular species of the group on the one hand, and the omul, peled, tugun and chir, on the other. Within the group, one can note the rather high genetic similarity of the Ob whitefish, Ussuri whitefish and muksun (P 0.10-0.21; H 0.01-0.06)

A representative of the genus **Stenodus**, the nelma, has preserved a considerable similarity with the whitefish in the majority of study enzyme systems. Low P (0.10 - 0.18) and H values (0.02) have been noted in the two study populations of this species.

The lowest average heterozygosity (0.002) and polymorphous loci ratio (0.04) in the subfamily have been obtained for the round whitefish. The reasons for this obviously lie in peculiarities of the formation of the Asian populations of this species. In the round whitefish populations of North America where according to current opinion the historical center of emergence of the species of the genus **Prosopium** is located (Booke, 1968),enzyme locus polymorphism is quite widespread (May, 1980).

It should be noted that the average estimates of genetic variability in whitefish, including available data on the North American (Ihasen **et al.**, 1981) and the Scandinavian populations of the species of the genus **Coregonus** (Vuorinen, 1981, 1984) are higher than those known for the majority of salmonids (Altukhov, 1983).

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GENETIC DIFFERENTIATION IN THE ASIAN O. GORBUSCHA

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Investigations of the population structure of the pink salmon /110* have been under way since the 1920s (Pravdin, 1929). However, despite great efforts, many features of the population organization of the species remain controversial. A number of investigators agree in the opinion that the pink salmon has a rigid multilevel population structure corresponding to the local stock concept (Altukhov **et al.**, 1983; Gagal'chii, 1985, 1986). On the other hand, the concept exists of total panmixia within the limits of this species (Aspinwall, 1974). Glubokovskii and Zhivotovskii in 1966 proposed the "fluctuating stock model", according to which the number and volume of pink salmon populations are subject to /111 periodic changes.

Using electrophoresis in starch and polyacrylamide gels, we investigated pink salmon samples from the rivers of Primor'e, Sakhalin and Kamchatka. More than 6,000 individuals have been analysed for 5-7 loci. The genetic similarity between samples was estimated by Nei's index (1978). Statistical significance was measured by the chi-square test (Nei, Rouchoudhury, 1974). Rao's method (1980) was used to construct clusters by genetic distance matrices.

Comparison of the allele frequencies by Nei's index revealed a considerable similarity between pink salmon samples both from the same region and from geographically distant localities. The differences between samples from rivers within particular

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generations are as a rule unreliable. There is therefore no sense at all in clustering by these characters. Reliable differences are detected between combined regional samples of different generations. On the basis of the local stock concept one would expect that the affinity of pink salmon samples within regional groupings would be greater than between them. However, sufficiently isolated aggregates corresponding to regional spawning groupings can not be distinguished on the basis of genetic characters. Combined samples of even and odd years, the genetic differences between which are statistically substantial, form two non-intersecting, isolated clusters.

The absence of regional confinement of samples may be the result both of substantial intermingling as well as of the influence of selective processes on the study characters. Comparison of our experimental findings with existing stochastic population structure models shows that the heterogeneity of allele frequencies which we have observed in a number of cases appears to be indicative of the influence of differentiating natural selection. However, it is also true that the character set which we used reflects the influence of migration and isolation processes. Otherwise we would not have observed such an obvious picture of differentiation of adjacent generations given the homogeneity within these generations. In addition, the results of tagging and ecological observations suggest that homing is less characteristic of the pink salmon than of other salmonid species (Levanidov, 1969; Tekagi et al., 1981). Thus, the comparatively slight genetic differentiation of the species may be explained /112
primarily by migration pressure.

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CHARACTERISTICS OF MORPHOGENESIS OF KIDNEY IN ATLANTIC SALMON SALMO SALAR.

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The aim of the present work is to study the formation and /112* development of the kidney in Atlantic salmon **Salmo salar** L. We studied Atlantic salmon embryos, larvae, fry, fingerlings, yearlings and two-year-olds cultivated at the Knyazhegubsk fish rearing station (Murmansk oblast).

A thick vascular plexus (the glomus), formed by the capillaries of the arterioles, originating in the aorta, is determined in the anterior end of the body on the ventral side under the gut in Atlantic embryos on the 97th and 148th days of embryonal development. The glomus is submerged in a cavity the walls of which are lined with flat epithelium. Several pairs of renal tubules fall into the glomal cavity. The paired prerenal (wolffian) ducts are situated retroperitoneally at the dorsolateral wall of the embryo body in the direction from the head to the tail region, where the ducts, gradually converging, merge and open into the cloaca. Dorsally along the ducts in the caudal direction, closely adjoining their basal membranes, a compact mass of cellular strands of intermediate mesoderm is noted. A characteristic feature of these observation dates is the large number of mitoses both in nephrogenic tissue cells, as well as those of the glomal epithelium and the renal tubules. Thus, in the study Atlantic salmon embryos, there is a provisory organ - the pronephros, localized in the cranial region of the body and consisting of the glomus and the pronephric ducts which are

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connected with it. The formation of the glomeruli and tubules of the mesonephros - the definitive excretory organ of fishes, caudally of the pronephros from the cellular strands of the intermediate mesoderm is observed in Atlantic salmon larvae after the emergence from the egg membranes (7.41 and 76 days). The neck, a proximal segment with two compartments and a distal segment are differentiated in the tubule system. The number of mesonephric tubules increases sharply in fry and fingerlings. In the cells of the first compartment of the proximal segment, the primary and /113
secondary lysosomes appear alongside numerous apical electron-dense tubular structures. In the cells of the distal tubules, the folds of the plasmalemma and the mitochondria which they enclose form a peculiar basal labyrinth. Good structural preservation of the pronephros is noted at these times, initial features of reduction of the pronephros being observed only in Atlantic salmon yearlings. Ultrastructural studies of mesonephros cells in yearlings and two-year-olds indicate its morphological maturity.

A number of important facts should be pointed out in analyzing these results. The formation and development of the definitive kidney in the Atlantic salmon occupies a prolonged period of time - more than a year. An active role in excretory processing in embryos and larvae belongs to a provisory organ - the pronephros. At a later period (fry, fingerlings and yearlings), parallel functioning of the pro- and mesonephros occurs. It is likely that in the postnatal ontogeny of the excretory system, the function of the glomus, the basic structural component of the pronephros, persists until the new structures - the glomeruli, have become sufficiently complete. According to Dloug **et al.** (1981), changes in feeding stages in animals are inevitably accompanied by brief fluctuations in the osmotic concentration of the fluid of the internal environment, which should thereby be controlled more effectively. In the Atlantic salmon, such fluctuations can arise in the larval stage on the transition from endogenous to exogenous feeding (in our material - larvae on the 76th day after emergence from the egg shell). Considering that by this time the mesonephros is still in the formative stage, this period should be considered critical both for the development of the kidney as well as on the whole for the formation of the osmoregulatory mechanisms in the Atlantic salmon.

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DEVELOPMENT OF SEXUAL GLANDS OF RAINBOW TROUT SALMO GAIRDNERI RICH DURING POSTRADIATION PERIOD. IRRADIATION OF LARVAE AGED 13 DAYS AFTER HATCHING.

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The detailed study of the development of the sexual glands /117* in the early ontogeny of the rainbow trout, and the influence on this process of extreme factors is important for the cultivation of spawners and commercial trout farming. Knowledge of the most sensitive periods in trout gonad development will enable us to manage this process by purposeful influences on the sensitive stage.

The present study forms part of a series of works devoted to discovering the most sensitive stages in the course of the early gameto- and gonadogenesis of the rainbow trout (Zakharova, 1983; Chmilevskii, Zakharova, 1983; Zakharova, 1984). Roentgen irradiation was used as an experimental factor by virtue of its penetrating ability and suitability for convenient dosing. The effect of radiation on the development of the gonads of rainbow trout larvae which had been exposed to roentgen irradiation at the age of 13 days after hatching was studied (doses of 25, 350 and 1000 R). At the time of irradiation, the gonads contained mainly primary cells in resting condition. The duration of the experiment was 4 months. All the results obtained have been analyzed according to the usual histological procedures.

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Substantial changes in the course of gameto- and gonadogenesis in the experimental fishes were observed in the experiments with roentgen irradiation; a clear relationship was noted between the processes of sexual cell death and the times and rate of gonadal development (histological and anatomical differentiation), gonadal regeneration times and irradiation dose. An irradiation dose of 25 R did not cause substantial disturbances in gonadal development and in the gametogenesis of the fishes. Irradiation doses of 350 and 1000 R had a striking effect, which increased in proportion to the dose.

On comparison of the results obtained with those of the other experiments in this series on the sensitivity of particular stages in gameto- and gonadogenesis to roentgen irradiation, it was found that the period in question (age of fishes 13 days, gonads containing mainly primary cells in resting state), is the most sensitive for the rainbow trout. In this experiment, the /118
restoration of gamete quality occurred only in the fishes irradiated at a dose of 350 R, while restoration of their number was not observed (doses 350, 1000 R). In the variant with irradiation dose 1000 R, the gonads did not reach the control level in development of anatomical structure as well. In both variants, fish were noted in which the gonads lagged in development, as well as sterile individuals, the number of which increased with the dose.

Somewhat different results have been obtained on other fishes. When fish whose gonads contained mainly primary cells were irradiated, there was as a rule regeneration of gamete composition in the postradiation period.

The results which we have obtained obviously confirm once again that the effect of radiation depends not only on the exposure dose, but also on the initial condition and functional activity of the sexual cells at the time of exposure, individual peculiarities of different fish, as well as on the species affiliation of the organism.

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ON THE PARALLELISM OF LEVELS AND MECHANISM OF GENOMIC DIVERGENCE IN STRUCTURAL ORGANIZATION OF KARYOTYPES IN SOME SPECIES OF SALMONID FISHES FROM GENERA SALMO AND HUCHO

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In representatives of the Atlantic salmon of the genus **Salmo** /118*
and the taimen of the genus **Hucho**, which are rather close evolutionally, **Hucho** having appeared earlier (Norden, 1961; Rounsefell, 1962, etc.), some species are subdivided into two similar levels of structural organization of the karyotypes. Thus, in salmon of the genus **Salmo**, one level is represented by the karyotype of a species which is distributed in Eurasia, the sea trout (**S. trutta**): 2n=78-82, NF=98-102 (Dorofeeva, 1965; Nygren **et al.**, 1971; Kaidanova, 1974, 1975; Hartley, Horne, 1984, etc.), while the other has been found among the Pacific salmon - Clark's salmon (**S. clarki**): 2n=64-68, NF=104 (Gold **et al.**, 1977; Loudenslager, Thorgaard, 1979). Similarly, in the genus **Hucho**, one level of karyotype structure has been found for the species known /119
as the European (**H. hucho**) and Siberian (**H. taimen**) taimens: 2n=82-84, NF=100-102 (106) (Dorofeeva, 1977; Sofradzija, 1979; Reb, Liehmann, 1982), while the other is found in a migratory species from the Pacific basin, called the Sakhalin taimen (**H. perryi**) after the place where it is mainly distributed: 2n=62, NF=100 (Anbinder **et al.**, 1982; Vasil'ev, 1985).

In connection with the definite differences in the Eurasian and Pacific species of the genera **Salmo** and **Hucho**, the necessity was noted for distinguishing them into the subgenera **Parasalmo** and **Parahucho** (Vladykov, 1963) or even genera (Glubokovskii,

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Glubokovskaya, 1981, etc.). Moreover, on the basis precisely of karyological findings, the question has been discussed as to the parallel evolution and phyletic unity between the Pacific genera **Parahucho-Parasalmo** and the Eurasian genera **Hucho** and **Salmo** (Vasil'ev, 1985). Consequently, evaluation of the mechanisms of the formation of the above mentioned levels of karyological divergence in each of these genera is very relevant.

As is known, the tetraploid origin is of special significance for karyotypes of the salmonid fishes. In this connection, the haploid sets of those salmon, in which the karyotypes are most approximate to the ancestral condition, should include paired chromosomes. In our opinion, genomic mutation of kayrotype structure, differing from the previously discussed type of rearrangements due to the tandem fusion of all the chromosomes of the haploid set in the species formation of the Atlantic salmon (Zelinskii, 1985) in that only centric fusions of unibrachial (telo-, acrocentric) chromosomes are likely, is possible on this basis. Subsequently, the process of zygote formation takes place from the genomically reorganized gamete and the normal gamete of the progenitor. In the case of the genus **Salmo**, these transformations might have occurred in the following manner. If the original gamete had a karyotype structure n=41 m(sm)=10, t(s, st)=31, then it was transformed as the result of the genome mutation of the unibrachial chromosomes to the following structural characteristics: n_1=26, $m(sm)_1$=25, t(s, st)=1. As a result, the zygote is characterized by the following chromosome set, which differs considerably from the karyotype of the progenitor: 2n'=67, M(SM)'=35, T(A,ST)'=32, NF'=102. Subsequently, due to the balanced ratio of the gametes, karyotpes 2n'=68, 2n'=66, corresponding to the real karyotypes of the subspecies of Clark's salmon, could have been formed. Of course, the formation of the karyotype of the Sakhalin taimen could have been achieved in a similar fashion. /120
The elimination of certain chromosomes, as well as special mechanisms of sex chromosome transformation, might have influenced the final values of the karyotype structure. However, as we see, on the whole, this mechanism confirms the possibility of parallel divergence of karyotypes in these genera of salmonid fishes and to some extent diminishes the importance of such karyological differences in the content of taxonomic definitions.

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Source: **Sovremennoe sostoyanie issledovanii lososevidnykh ryb** (Current status of research on salmonid fishes). **Tezisy III Vsesoyuznogo soveshchaniya po lososevidnym rybam** (Abstracts of the III All-Union Conference on Salmonid Fishes). Tolyatti, USSR, 1988, pp 120-121.

ON SIGNIFICANCE OF ADAPTIVE AND GENETIC CHARACTERISTICS IN FRESHWATER POPULATIONS OF ATLANTIC SALMON USED IN AQUACULTURE

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As is known, the use of populations of the migratory form /120* of the Atlantic salmon **Salmo salar** L. in aquaculture has been expanding considerably in a number of countries. Here in the European north of the Soviet Union, conditions for such work within the range of this species are less favorable owing to the severity of the climate. Nevertheless, efforts are being made to realize its economic potential in aquaculture. Attention is also being given to freshwater populations living in the major lakes in the White Sea-Baltic watershed. Of course, problems have arisen in the preliminary stages involving the selection of the most productive populations of lake salmon best adapted for domestication, the utilization of special culture methods, and the preservation of the genofond of stocks selected for use in aquaculture. In addition, there are problems with sources for warmwater culture.

On the basis of comparative materials, mainly on the ecology and structure of lake salmon populations, we have analyzed some of their adaptive traits which are associated with a complex of environmental factors and perhaps depend on the population founders. These include, in particular: the considerable (up to 80%) increase in the portion of females in the spawning stock, the reduction in the growth rate in the foraging period and the increase in the portion of repeatedly maturing fish, etc.

*The numbers in the right-hand margin indicate the corresponding pages in the original. - Transl.

On the whole, among the lake salmon populations, the Lake Ladoga salmon stands out in growth rate, and the salmon of a number of local stocks of the Lake Onega population in size and weight /121
of spawners. The latter is due to the increased duration of life in the foraging period - up to 6-9 annual cycles without sexual maturation. However, as analysis of the spawning stocks of the Shuya R. salmon (Lake Onega) in 1986-1987 shows, the structural indices of naturally and artificially reproduced spawners can deteriorate. Selection work is necessary to prevent a decline in the size and weight of sexually mature fishes (selection of spawners for artificial reproduction and for escapement on the basis of maximal size and growth rate).

In order to meet the numerous requirements for the development of freshwater salmon aquaculture proper, repeated utilization of spawners will probably be necessary, that is, fish with polycyclic maturation must be selected. The ratio of dwarf males can also apparently be reduced by selection of spawners yielding a smaller number of them in progeny. Dwarf males must be selected out after sexual maturity as well, by applying sterilization methods with subsequent utilization as planting stock in aquaculture. Strictly speaking, sterilization of the entire progeny is possible as one method of obtaining output in aquaculture. This is important in that limitations on the duration of the growth period to sexual maturation are removed in sterile fish.

Obviously, many problems of the adaptive peculiarities of lake salmon will only be answered by their comparative cultivation in aquaculture. In addition, crossing of salmon representing different lake populations should be done in order to check the heterosis effect for a given form of the species.

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THE EFFECT OF SALINITY ON THE ENERGY METABOLISM OF O. KISUTCH DURING SMOLTIFICATION

By V.V. Zinichev and V.S. Varnavskii
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Vladivostok.

Experiments have been done to evaluate the oxygen consumption /122* rate in coho salmon during the river period of life (parr) and in fishes caught in the polyhaline (18-30‰) zone of Avachinsk Bay on the migration route from the river to sea (smolt). The oxygen consumption was measured using oxygen gages and an automatic device with continuous registration of results over a period of several days. More than 500 measurements of oxygen consumption were done in 16 fish weighing 7.0-8.5 g at a temperature of 15°C. The minimal oxygen consumption values, which were taken as the standard metabolism, were established 2-2.5 days after the fish were placed in the respirometers. The water was replaced at this time: for the smolts - the saline water (27.5‰) was replaced by water with a salinity of 12 and 0‰, for parrs - fresh water was replaced by salt water (25 and 27.5‰). The oxygen survey was continued for another 2.5-3 days. The water was replaced unnoticed by the fish: the water was allowed to pour out and the water of the required salinity was fed in from another container due to the level difference.

A salinity change within the tolerance range has a considerable effect on the oxygen consumption of coho salmon smolts. A decrease in respiration by 3-4% and 7-8%, respectively, was observed after the replacement of sea water by subsaline and fresh water.

The replacement of fresh water by sea water caused a 23-24%

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decrease in oxygen consumption in parr-juveniles. The new level of standard metabolism was established at 0.1 mL O2/g°h and remained quite stable for the next 60 hours of residence in the fishes in the respirometers. A 7-8% reduction in respiratory level was observed in the parr-juveniles after the fresh water was replaced by subsaline water (15‰).

For smolts, the oxygen consumption in the fresh, subsaline and sea water was respectively 0.148±0.008, 0.157±0.003, 0.162±0.003 (mL O_2/g.h), for parrs - 0.141±0.003, 0.137±0.003, 0.100±0.001 (mL O_2/g.h).

Thus the influence of salinity on oxygen consumption in salmonid fishes is more pronounced than that of water temperature and fish size, as far as one can judge from published findings (Vinberg, 1956; Ivleva, 1981; Smirnov **et al.**, 1986 and others). Nevertheless, oxygen consumption must be taken into consideration /123 in determining the saline optimum in salmonid fishes during the change in habitat on the basis of the principle of energy expenditure minimization in optimal conditions, which has been successfully used in establishing temperature optima (Ozernyuk, 1985; Alekseeva **et al.**, 1985).

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EFFECT OF SALINITY ON ENERGY METABOLISM IN ACCELERATED YOUNG-OF-THE-YEAR O. KETA AND AN ASSESSMENT OF SALINE OPTIMUM.

By V.V. Zinichev, V.S. Varnavskii and O.N. Saravanskii

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Analysis of the water-salt metabolic system, on the basis of /123* which a conclusion is drawn as to change in the type of ionic regulation in salmonid fishes, is insufficient in order to assess the optimal salinity of the water for development and growth during the habitat change.

The aim of the present work was to evaluate the optimal water salinity conditions for the example of accelerated chum young of the year of two size groups: I - body mass 1.0-1.2 g (similar to that in young of the year migrating by river), II - mass 3-5 g (similar to that in chum during the early salt-water period). The fish were maintained in water with a salinity of 0, 6, 12, 18, 24 and 30‰ at a water temperature of 13°C. After 10 and 20 days of growth, the oxygen consumption (OC) rate was determined and the body mass increment was determined. The dependence of total energy expenditures on increment of a unit of body mass (Σ Q) on salinity of the water, was used as an estimator. The value of Σ Q was determined from the formula: $Q=4.86.OC.T.M$, where Σ Q is the total energy expenditure, in calories, OC is the rate of oxygen consumption in mL O_2/g.d, M is the body mass in grams, 4.86 is the oxycaloric coefficient.

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The dependence of ΣQ on water salinity was parabolic in the first 10 days of growth of chum young of the year in salt water and was approximated by equations:

for group I $\Sigma Q = 0.0068\ s^2 - 0.198\ s + 2.679$.

for group II $\Sigma Q = 0.020\ s^2 - 0.445\ s + 3.389$, where is the salinity of the water in ‰. The parabolic extrema corresponding to the minimal energy expenditures occurred in the /124 zone of isotonicity (14.5‰ for group I, 11.1‰ for group II). After 20 days, the minimal ΣQ values for the study young of the year groups were observed in the 20-30‰ salinity range.

V.S. Ivlev's K_2 coefficient (1939) is often used to describe the relationship between growth and energy expenditures. For the study young of the year groups, the dependence of K_2 on salinity of the water is approximated by parabolas which are a mirror reflection of those describing the dependence of ΣQ on salinity. Analysis of ΣQ values enables determination not only of the optimal growth zone, but also of the optimal regimes for development at early stages of embryogenesis, as has been shown for the example of estimating the temperature optima for the development of fish spawn (Ozernyuk, 1985). Consequently, the proposed method for evaluating the optimal salt regime is more universal than analysis of K_2 coefficients of growth efficiency.

When Q is expressed as a % of its value at the extremum, taking the optimal salinity as the reference point, and the parabolas obtained for small and large fish are matched, the zone where Q values are close to the extremum is considerably wider in the group of small fish than in the large fish group. This method of data comparison shows differences in energy expenditures on adaptation in the study salinity range in small and large chum young of the year and probably reflects differences in their euryhalinity: the small fingerlings are more euryhaline than the large ones.

The possibility is assessed of experimental estimation of the degree of euryhalinity and the saline optimum in salmonid fishes during the change in habitat.

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DIFFERENCES AMONG PROGENY AND VIABILITY OF O. KISUTCH DURING EARLY ONTOGENY

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Variability of characters serves as an indicator of the normal /128* condition of juveniles and their viability and reflects the diversity of conditions of embryonal-larval development and existence of juveniles. The existing large body of data on the dissection of coho salmon redds and morphological variability at the early stages of development made it possible to do an analysis of variability in morphological characters and survival of larvae in redds.

Larvae are the progeny of one female; they are extremely heterogeneous in degree of development, sizes and body weight. Spawn at the eye pigmentation stage, larvae at the moment of hatching of different length, and larvae of the same size but with different form of yolk sac and degree of organ differentiation are situated in the redd at the same time.

Progeny which has a large variability of sizes as a rule gives a higher waste over the development period. Thus, with a survival rate of more than 60%, the average coefficient of variation (cv) in the length of larvae is 4.8; in the case of high size variability -cv 11.2, the survival rate in redds is considerably less than 60%. The indices of correlation between larval survival and the cv of their length and plastic characters

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are 0.79 (m_r=0.20, t_r=3.95) and 0.91 (m_r=0.14, t_r=6.5), respectively.

The variability in exterior characteristics, embryo and larval body mass in coho are in turn an indicator of the level of morphological differentiation. This is also expressed in the structural heterogeneity of the yolk sac - in the number, size and arrangement of fat drops, and in the rates of its resorption, as well as in the dynamics of fat deposition in the body cavities, that is, in the different level of fat metabolism.

During the late larval and fingerling period of development, when the larvae make the transition to exogenous feeding and the yolk sac is resorbed. their survival will depend to a large extent on the preparedness of the larvae for taking of external food, given a sufficient amount of it in the body of water. The degree of such preparedness can be judged by the number, structure and /129
average maximal length of the pyloric caeca, expressed as a percentage of body length, and the fatness of the late larva. Larvae with a lesser amount of fat and undeveloped pyloric caeca remain in the ground, despite their suitable size and degree of yolk sac resorption.

Splitting into groups differing in the level of fat metabolism occurs already at the late larval stage. Subsequently, as these fish develop, the difference in both feeding and growth as well as time of sexual maturity increases.

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ON INTERRELATIONSHIPS AMONG VARIOUS FORMS OF VARIABILITY IN EVOLUTION OF SALMONS

By V.N. Ivankov and E.V. Invankova
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The magnitudes of various forms of variability in salmons: /130*
morphological, genetic, karyological and ecological, are discussed on a comparative basis. These indices have been studied in various local populations, ecological (seasonal) races and between them.

It has been found that the magnitudes of these forms of variability in seasonal salmon races are inadequate. For example, such clearly differentiated ecological groups as the seasonal races of the Amur chum (differing in the dates and ecology of spawning, body size, rate of growth, egg size, amount of carotenoids in spawn, morphology of the body, karyotypes and other indices), show extremely slight differences in genetic-biochemical indicators (Kulikova, Salmenkova, 1979; Omel'chenko **et al.**, 1985; Viktorovskii **et al.**, 1986; Ivankova, Efremova, 1987).

On the other hand, differences in genetic-biochemical indices are incomparably more significant between local salmon populations (stocks) within races. This has been found by comparison of the polymorphism in enzyme proteins in the chum of the Amur, Sakhalin and Kuril fall race (Kulikova, Salmenkova, 1979; Altukhov, 1983; Ivankova, Efremov, 1987 and others), as well as the Okhotsk coast,

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Amur and Kamchatka summer chum (Viktorovskii **et al.**, 1986 and others). At the same time, the ecology of spawning and the morphobiological indices of the fish of the local populations both within the summer and the fall chum races are considerably closer while differences in karyological characteristics have not been found.

The following has been found in the study of differentiation /131
in the intraspecies units of the pink salmon. The salmon of adjacent generations (even and odd years) are clearly differentiated in karyology and biochemical genetics (Aspinwall, 1974; Salmenkova **et al.**, 1981, etc.). In the absence of differences in the ecology of spawning, migration dates and biological indicators, slight differentiation by morphological characters is noted. The seasonal races of the pink salmon are quite well differentiated by dates and places of spawning, fecundity, population structure and other indices (Ivankov, 1967, 1986), but are only slightly differentiated by enzyme systems and are practically homogeneous in karyological indices.

Differences in genetic-biochemical indices in local populations are still less pronounced, while at the same time, morphobiological indicators here are sometimes quite substantial (Birman, 19766; Enyutina, 1942; Ivankova, 1967, etc.). Similar data are available as well for other salmon species (sockeye, chinook, masu, etc.).

Consequently, the differentiation and in the end result, the evolution of species occurs by different pathways. In each particular case, some one form (or forms) of variability predominates for each species (or other systematic group). This might be differences in ecology, morphology, karyology, biochemical genetics or in other indices. It is thus evident that the evolution, hierarchical or affinity relationships of species (or larger systematic groups of organisms) can be elucidated only by studying the various forms of variability. One might otherwise arrive at subjective and most improbable constructions.

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PECULIARITIES OF EMBRYOGENY AND RESPIRATION OF RAINBOW TROUT IN CHRONIC INTOXICATION WITH SUBSTANCES HAVING HIGH CONTENT OF ACTIVE OXYGEN

By R.P. Ivanova, E.S. Zubkovich, A.F. Samylin, A.V. Gorokhov and V.D. Prokopenko

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In chronic aquarium experiments, we studied the effects of /132 different concentrations of substances (from 0.01 to 100 mg/L) with high oxygen content (hydrogen peroxide, perborate and sodium percarbonate) on features of embryogeny (survival rate, morphological characters, linear-weight dimensions, hatching dynamics) and respiration of rainbow trout. Respiration was assessed from the oxygen absorption of the developing rainbow trout embryos, which was determined by the manometric method in a Varburg apparatus. Hydrochemical indices of solutions (pH, oxygen content, permanganate oxidizability, mineral nitrogen, etc.) were determined in the process of the experiment.

Analysis of the results shows that all the study substances in high concentrations have an effect on hydrochemical indices: a sharp increase in oxygen content, a considerable inhibition of nitrification processes, and an increase in the oxidizability of solutions were observed at a concentration of 10 mg/L or more.

High concentrations of the study substances caused disturbances in the embryonal development of rainbow trout: a decrease in linear-weight dimensions, a disturbance of pigmentation, behavioral reactions, some acceleration of hatching of larvae, etc. have been noted.

It has also been shown that the study substances differ considerably from each other in the minimal concentration at which

depression of respiration was observed: 0.1 mg/L for hydrogen peroxide, 1.0 mg/L for sodium peroxoborate, 20 mg/L for sodium percarbonate. Moreover, the reduction in oxygen absorption is directly dependent on the concentration of toxic substance. High concentrations (100 mg/L) caused a depression of respiration in all cases by approximately 30-40% against the control.

These findings in all probability can be explained by the oxidation of embryo membrane polyenoic fatty acid residuals.

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EMBRYOGENY OF BROOK TROUT UNDER VARIOUS CONDITIONS OF ILLUMINATION IN CONDITIONS OF ARTIFICIAL INCUBATION

By T.S. Ivanchik and E.G. Prikhodskaya
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In connection with the development of coldwater fish culture, /133* establishing the causes of low survival of fish juveniles in artificial incubation, development of biotechnical measures and brood stock selection in order to obtain viable progeny are tasks of the first importance. Thorough knowledge of the specifics of fish development governed by their interrelationships with their environment, is also necessary.

It was of interest to establish the effects of carotenoid pigmentation of spawn on the viability of progeny at early stages of embryogenesis. Experiments were done in conditions of artificial incubation of brook trout spawn at the Lopushnyaksk trout incubatorium.

It was established that the rate of fertilization of eggs containing more carotenoids is higher than that of slightly pigmented eggs, although no reliable connection between these indices has been found. An inverse correlation has been found between the degree of egg pigmentation and elimination of juveniles. The minimal juvenile mortality (20.5%) is observed in middle-aged adults, in which the total reserves and concentration of carotenoids in the reproductive organs are maximal (1.60 mg%). The highest mortality is observed in embryos and larvae obtained from spawn of old females (73.4%) and yearlings spawning for the first time (61.8%) which produce poorly pigmented spawn (0.72-1.23 mg%).

It has been established that carotenoid reserves are depleted

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during embryogeny in brook trout. The change in content at different developmental stages varies and depends on conditions of illumination. At early stages (I-III), in daylight conditions, the embryos utilize 9.9-10% of carotenoids. Beginning with the gastrulation stage, diffuse daylight stimulates the rate of metabolic processes. Over this period, embryos in darkness and in conditions of infrared illumination consume only 4.2 and 4.7% of pigments. In connection with the intensified morphogenesis and the increase in the role of carotenoids as respiratory pigments, a more intensive utilization of carotenoids by the organism (20.9-23.3%) under the influence of diffuse daylight occurs at the stage of differentiation of the embryo into head and trunk segments (stage IV). Infrared light and darkness slow down their expenditure /134 to 9.9-10% and 13.4-16.3% respectively. By the time of organ differentiation (stage V), 31.4-35.9% of carotenoids is expended in diffuse daylight, that is 2.1-4.6% more than in infrared light and 15.1-19.0% more than in darkness. A critical moment in the development of brook trout at stage V is the appearance of the first movements of the embryos under the egg shells. Despite the considerable reduction in carotenoid reserves in embryos in diffuse daylight, these physiological traits apparently favor the normalization of gas-exchange. By the end of embryogenesis (stage VIII), carotenoid reserves are exhausted particularly in embryos which develop in daylight. In darkness and infrared illumination, 35.2 and 32.4% of pigments remain. Sparing consumption favors an increase in the viability of the developing embryos. Over the time of embryogenesis, elimination was 7.0% in darkness, 6.1% in infrared light, and 20.0% in daylight. The duration of embryonal and larval development averages 191 days in darkness, 170 in diffuse daylight. The illumination factor must therefore be taken into consideration along with other environmental conditions in fish culture practice.

The regulatory significance of various factors on the course of development of juveniles must be taken into account in improving the effectiveness of artificial propagation of salmonid fishes so that the formation of larvae to the downstream migrant stage corresponds to the dates of onset of biological spring in natural waters. The degree of carotenoid pigmentation of spawn can serve as one criterion for assessing its quality for fish-culture purposes.

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GENETIC DIFFERENCES IN MALES AND FEMALES OF O. NERKA OF DIFFERENT AGES

By L.V. Il'ina
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In order to determine the interrelationship of the size, sex, /134* age and genetic makeup of the Lake Azabache sockeye population, we examined the dynamics of allele frequencies of polymorphous loci of lactatedehydrogenase B1 and phosphoglucomutase in males and females of the two seasonal races, as well as the ratio of heterozygotous genotypes in fishes of different size and age. Analysis was based on samples collected from 1971-1984. /135

No differences were found in the allele frequencies of the two loci between males and females in the samples of each year in both seasonal races. However, differences do exist in the variability of allele frequencies in all the study years. In the sockeye of the spring race, the greatest annual variability has been noted for females in the PGM locus. In the sockeye of the summer race, reliable heterogeneity of sample frequencies is noted for males for both study loci. Differences exist in the genotype distribution between males and females: the females are more heterozygous for both loci; the females are characterized by a stable excess of heterozygotes for the PGM locus.

Since the males are more variable than the females in body size and age of maturation, the connection of these parameters with heterozygosity level was analyzed. We arbitrarily divided all the analyzed males into two groups: smaller than females and larger than females. No reliable correlation has been found for the LDH-B1 locus between the proportion of small males and

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heterozygosity of all males in samples. A reliable negative correlation exists for the PGM locus in the sockeye of the spring race, that is, larger males are more heterozygous. In the sockeye of the summer race, there is a reliable positive correlation: the level of heterozygosity for the PGM locus correlates with the rate of growth and sexual maturation of males.

Males and females belonging to the same size group, with identical marine age, differ in the freshwater period of life (1 or 2 years in freshwater) and consequently in absolute age. In the sockeye of the spring race, of the large males, the fast-growing males, who have spent 1 year in freshwater, are more heterozygous for both loci; in the medium-sized males, it is the slow-growing males who have lived 2 years in lakes (the latter differences are reliable). Three-year-old females of the spring sockeye race are more heterozygous for the LDH-B1 locus than four-year-olds of the same size; the opposite picture is observed for the PGM locus. On the whole, females are more heterozygous than males for the LDH-B1 locus; for the PGM locus, the females fall between the mid-sized and large males in the heterozygous genotype ratio. In the sockeye of the summer race, pronounced differences between fish with different duration of freshwater period of life appear only in mid-sized males. Unlike the fish of the spring race, the fast growing two-year-olds turned out to be more heterozygous for the LDH-B1 locus; for the PGM locus, the greatest ratio of heterozygotes is in three-year-old mid-sized males. The /136
genetic appearance of the sockeye population in each particular year is thus determined by the ratio of the sexes and size-age groups, as well as by proportion of fish of adjacent generations, differing in absolute age.

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DATA FROM CYTOGENETIC STUDY OF EMBRYONIC TISSUES OF SOME WHITEFISH SPECIES IN TYUMEN OBLAST

By N.A. Kabanova
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Determination of some cytogenetic characteristics of embryos obtained from paired and commercial crossings of spawners has been done in order to establish the peculiarities of each study population with respect to these indicators and the possibility of utilizing these indices as spawner quality criteria. //136

Study of the karyotype, plotting of the karyogram and determination of chromosome lengths was done using a standard microscope eyepiece grating and an Iskra-1256 computer.

The studies done showed that cytogenetic analysis allows one to determine causes of embryo death of a genetic (spawner compatibility, certain disturbances in the hereditary apparatus of egg cells and spermatozoa, etc.) and non-genetic nature (overripe eggs, violation of fertilization and egg storage biotechnology, etc.). It has been confirmed that embryos from different crossings can differ in the level and nature of chromosome breakage. Variations in the number of chromosomes have been noted for each embryo. We have shown that a greater diploid chromosome number (2n) is characteristic of whitefish embryos in the early blastula stage than at late stages of development. It has been found that the increased 2n value is due to the presence in the chromosome set of a corresponding number of "small" chromosomes. The number of such chromosomes can vary in different cells.

Thus, cytogenetic diversity of embryos is a precondition for characterizing different whitefish populations, for assessing spawners participating in crossings, and for determining their compatibility and quality of sexual products.

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ESTUARIES AS A CRITICAL PHASE IN DEVELOPMENT OF O. KETA

By A.M. Kaev
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Studies were done on the chum salmon of Iturup I., for which /137* a weak trophic link with the food organisms of rivers and migration to sea of 36 to 82% of migrants with a yolk residue is characteristic. After the downstream migration, the juveniles for a long time keep to the relatively freshened coastal shallows. The combination of the already grown fingerlings with migrants continuing to migrate from the rivers creates a considerable diversity of fishes at this stage. During the study, a hypothesis arose as to the dissimilar sensitivity of different juvenile groups to environmental factors. In each of 119 samples (10,137 spec.) collected since 1974, the juveniles were divided into three groups: with yolk residue (Schmidt's length 32-42 mm), without yolk (33-40 mm) and grown up (more than 40 mm), the first two groups representing recent migrants. The average values and coefficients of variation were determined, as well as the maximal stomach fullness indices. The variations in these indices were analyzed in low (less than 100°/ooo), medium (100-250°/ooo) and high (more than 250°/ooo) stomach fullness index variants, reflecting to some extent the food supply factor. At the same time, increase in the variability of the stomach fullness index was considered to be a consequence of deterioration in feeding conditions, as is confirmed by the results of the study of intraspecies and interspecies relationships in the feeding of chum and pink salmon.

Differences were detected in the stomach fullness indices between the juveniles of groups segregated. In all variants, the fully-formed fingerlings fed more successfully. In the high stomach fullness index variant, the small juveniles without yolk

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approximated the fully formed ones in feeding indices, while in low stomach fullness index conditions, these indices deteriorated most in the larvae. In addition, samples taken in gale conditions with marked cooling (to 1-3°C) were studied by these variants. In this case, the feeding of juveniles with yolk was poor even against the background of a general deterioration in stomach fullness indices for all the fish. This confirms the previously stated opinion as to an increase in mortality under the influence of random environmental factors. The high death of chum from fish hatcheries, migrating to sea for the most part at the larval stage, is also apparently due to extreme situations. Changes in the /138
condition factor, which not only decreased on average in the migrating juveniles, but whose range of fluctuations also increased sharply, largely agree with the great variability in stomach fullness index in juveniles which have recently migrated from the rivers. The condition factor gradually increased and its amplitude decreased in the fully-formed fingerlings, and these indices had relatively stabilized when the chum reached a length of 44-47 mm.

This increase in juvenile diversity after the downstream migration apparently reflects a complex process of adaptation in the estuary, connected with the transition to active exogenous feeding in different salt and thermal conditions, fluctuation in the composition and biomass of food organisms, etc. In this connection, the evaluation of juvenile foraging conditions only on the basis of variation in certain environmental parameters appears to be inadequate. For the Iturup chum, an attempt has been made to evaluate the effectiveness of foraging on the coast on the basis of variability in the growth of juveniles, which enabled satisfactory prediction of the return of adult fish, and this indicates that the mortality of salmon following downstream migration is most variable precisely on the seacoast. Another advantage of the method is the relatively low cost of work in estuaries, which does not require the use of large specialized ships.

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STUDY OF GENETIC POPULATION STRUCTURE OF O. GORBUSCHA IN SAKHALIN-KURIL REGION BY MULTIVARIATE ANALYSIS

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As input data, we used genotypic frequencies for four loci /144*
encoding MDH, -GDH, PGD and PGM allozymes in pink salmon samples collected periodically during the spawning run in various rivers in the Sakhalin-Kuril region in 1977-1980. The total number of study samples is 124, which represents the spawning populations of 16 rivers and includes a total of 9053 analyzed specimens from two generations of even and two generations of odd years.

To analyze the data, we calculated modified Zhivotovskii's similarity indices for all the compared samples within the "even" and "odd" generations. The resulting similarity matrices were analyzed by multivariate scaling and Rao clustering methods. In the end, the samples were represented as points in a coordinate system of the main components, plotted in accordance with the specified threshold values of the similarity indices. The resulting data allow one to assess genetic variability over the range and the time of the spawning run, to obtain qualitative pictures of the degree of exchange between the groups distinguished and on this basis to assess the pressure of taxonomic factors conducing to the formation of the population structure. Genetic heterogeneity shows up on analysis of the entire data set, including observations for the region over the spawning period, as well as on analysis of data collected during this period on particular rivers. Similarity indices of genotypic makeup of samples from different rivers are similar to the average

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similarity estimates for the entire study region. In some cases, the genetic diversity of pink salmon spawning even in relatively small rivers surpasses the amplitude of variability for the study loci on the entire range in the Sakhalin-Kuril region.

Three main groupings have been distinguished: of the south- /145
eastern and southwestern coast of Sakhalin and the Kuril grouping. The interpretation of the groupings corresponds to the geographic confinement of the majority of the samples which comprise them. This subdivision is traced in all the study generations of even and odd years. It is less pronounced in even years which is perhaps due to a less clear-cut structure and/or lesser volume of material collected in even years.

These results indicate that the degree of exchange between the groups distinguished is high enough at least to level out differences in the genotypic makeup of the progeny of spawners from different regions. Local selection is in our opinion the most likely factor resulting in genetic differentiation of the pink salmon. In analyzing only the reproductive period, one can not assess the contribution to the total differentiation by the spawning populations of individual rivers, or get a picture of the resultant effect of the two stages of spawners-larvae-spawners cyclic selection (Altukhov **et al.**, 1987; Zhivotovskii **et al.**, 1987).

In comparing these results with the fluctuating stock concept (Glubokovskii and Zhivotovskii, 1986), one must refine the local stock definition. If by local stock we understand the spawning population of a particular river, then we must acknowledge the correctness of the authors. If the local stock is considered as the aggregate of the spawning populations of some region, then we must note the discrepancy between our results and the features of the population organization of the pink salmon described by the authors of the local stock concept. We observe the reproducibility of genetic differences in generations, geographic confinement and the existence of more or less clear boundaries of such aggregates. The considerable migration exchange within the region may be due to the intensive fishery and the massive transfers of fertilized eggs within the region. When data on the populations of Western Kamchatka are included in the analysis (Gagal'chii, 1985, 1986), the effects of isolation by distance show up clearly. The average values of the similarity indices fall with increase in the geographic distances separating the populations of the compared regions.

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GENETIC POPULATION STRUCTURE OF O. GORBUSCHA

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The space and time heterogeneity of the frequencies /149* of the predominant alleles of five enzyme loci Mdl-3,4, 6Pgd, Pgm, Agp, has been studied in five successive generations (1979-1983) in populations of pink salmon - the most numerous salmon species. About 4,000 specimens of adult pink salmon, as well as more than 1,000 juvenile and larval specimens, from the populations of 22 rivers of the Far East of the USSR have been studied.

On the basis of allozyme variability, using relative estimates of intra- and interpopulation differentiation, it has been concluded that the genetic divergence within pink salmon populations of different rivers does not differ from that within such large population aggregates as, for example, the Sea of Japan pink salmon. Thus, the aggregates of individuals spawning within a particular river system in this species are not genetically differentiated population units self-reproducing in generations, that is, they are not local stocks in the usual salmon breeding sense (Ricker, 1972). Only large population series, such as the Sea of Japan pink salmon, can be considered independent populations or local stocks. This idea accords best with Gritsenko's previously stated opinion (1981) and does not contradict other population genetic data (Altukhov **et al.**, 1983; Beacham **et al.**, 1985; Gagal'chii, 1987). The level of genetic divergence in different local stocks is very slight, which is due to the high interpopulation exchange in the pink salmon, and apparently to stabilizing selection, associated with the specific ecology of the species. The genetic population structure

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of the pink salmon is basically made up of three levels: 1. Adjacent, completely non-overlapping populations. 2. Large, geographically remote stocks or population systems, which preserve their genetic distinctiveness in generations. 3. Subpopulations; the labile structures that make up population systems and arise as a result of the differentiating effect of natural selection and a combination of random factors (drift, fluctuating direction of spawning migration). /150

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GENETIC STUDIES ON SALMONID FISHES

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Salmon (genera **Salmo**, **Oncorhynchus** and **Salvelinus**), as well as /153* some whitefish (genus **Coregonus**), have recently been the objects of intensive genetic investigations. These studies are following several most important directions.

Population-genetic studies of salmons and whitefish. The works in this area pursue the goal of obtaining the most complete possible information on the population structure of particular species and the genetic structure of their component populations. The greatest successes have been achieved in the study of the intraspecies structure of Pacific salmon (sockeye, pink salmon, chum), salmon of the genus **Salmo** (Atlantic salmon, rainbow, brook and Sevan trout, sea trout and Clark's salmon) and chars of the genus **Salvelinus** (American brook and lake char, Arctic char). It has been established that each salmon species has its own characteristic species specific genetic population structure and a particular relationship of intrapopulation and interpopulation genetic variability. The results of the study of three salmon species are of particular interest.

1) The sockeye is distinguished by a local genetic differentiation which is stable over time and by the presence of a complex intrapopulation age and sex structure. Different groups within the population differ in gene frequencies, this differentiation having an adaptive nature.

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2) The pink salmon is subdivided on all of its vast range into non-intermingling populations of even and odd years - essentially isolated races or subspecies. The genetic differences between them have a stable nature and maintain the same sign both in the Asian as well as the American part of the range. Exchange of individuals is possible between adjacent pink salmon populations, so that local genetic differentiation is relatively unpronounced, but genetic differences undoubtedly exist between the stocks of the major regions.

3) Rainbow trout and steelhead are represented by a large number of genetically differing migratory and freshwater populations and at the same time have a high degree of intrapopulation genetic variability.

Karyological studies of salmon. Salmon karyotypes are now /154
being studied using improved methods of differential chromosome staining, and this has made it possible to reconsider some obsolete karyological data and to discover previously unknown features of karyotypes of salmonid fishes. The most important result of karyological research is the proof of the constancy of the karyotype in the majority of salmon species: the chromosome number remains unchanged in the overwhelming majority of individuals within a given species. Intra-individual variability of karyotypes (mosaicism) in adult individuals is also relatively small, apparently being confined only to the early stages of embryonal development. There are however polymorphous species as well, which include the rainbow trout (chromosome number varies from 59 to 65) and the pink salmon (52-54). Some chars of the genus **Salvelinus** are also polymorphous. In all polymorphous species, variation in the chromosome number is associated with Robertson translocations. Sexual dimorphism is observed in sockeye - the females have 58 chromosomes, the males 57 in most cases; the male kayrotype includes one unpaired large metacentric chromosome which is evidently formed by fusion of two small acrocentric elements. The presence of unpaired sex chromosomes in coho, chinook, Atlantic salmon and rainbow trout has been established by genetic methods.

In all salmon of the genera **Salmo** and **Oncorhyncus**, the nucleolus organizing regions (NOR) are confined to the chromosomes of a single pair, while in char of the genus **Salvelinus** their number runs to four or even six.

Artificial production of triploids and tetraploids and sex regulation in salmons. Work in this direction has been proceeding particularly successfully in the last decade. The possibility has been shown of obtaining (by means of temperature effects or high hydrostatic pressure, gynogenesis and hybridization) commercial quantities of sterile triploids in rainbow trout, chinook, coho and other species, cultured in ponds and tanks. It has been established that triploids grow considerably more quickly than diploids during the sexual maturation period. Procedures of hormonal sex regulation have been developed in detail. These, in combination with gynogenesis make it possible to obtain progeny of

one (desired) sex in virtually all salmon species.

Selection work with salmon fishes. In addition to rainbow trout and steelhead, Atlantic salmon and sea trout, Clark's trout and two species of char of the genus **Salvelinus**, as well as (in the USSR) the Siberian whitefish ("peled" - **C. peled**), have recently become breeding objects. Strains having different sets of commercially valuable traits, including resistance to diseases and unfavorable environmental factors, have been created in breeding work in a number of countries. New valuable breeds of trout and other salmon fishes may be created on the basis of these strains in the near future. Of the studies being done in the USSR, one should note particularly the selection-genetic studies of the peled, in which methods of biochemical genetics are being successfully combined with the study of inheritance of quantitative traits, including the very important productivity indices. Methods of selecting whitefish are being improved at the same time. Breeding work with the Atlantic salmon and coho which have been started in a number of Western countries, pursue the goal of deriving breeds adapted for cultivation in tanks. /155

An important result of works with various salmon and whitefish species is the discovery of strong genetic differentiation in juveniles in the process of development and growth and the existence of selection in favor of heterozygotes for protein loci. Genetic differentiation in juveniles must be taken into consideration in the reproduction of salmon at fish hatcheries.

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SMOLTIFICATION AND DEVELOPMENT OF OSMOREGULATORY SYSTEM IN SALMON SPECIES WITH DIFFERENT ECOLOGY

By L.S. Krayushkina
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In the life cycle of migratory salmon species whose biology /164* is associated with the sea, the period of smoltification, which occurs in freshwater conditions, is characterized by a complex process of formation of the organism, as a result of which the juvenile acquires the ability to live in salt-water environment.

The increase in eurybionticity of juveniles in the course of smoltification is associated with the morpho-functional development of different systems, an increase in their physiological and biochemical activity and by the establishment of a functional interrelationship among them, and is also accompanied by a change in the behavioral reactions of the juveniles.

An important aspect of the smoltification process is the /165 development of an osmotic homeostatic mechanism ensuring the maintenance of relative constancy of osmolarity of the internal environment in juveniles on transition from freshwater to marine conditions after migration from the river.

The work of the effector organs of the osmoregulatory system (chloride cells of the gills, the kidneys and to some extent the gut), is regulated by the neuroendocrine system (hypothalamo-hypophysial neurosecretory system) and the endocrine glands (interrenal bodies and thyroid, Stannius' corpuscles, etc.), which play a multiple role in regulating the vital processes.

On the basis of an integrated study, which included physiological, biochemical, histological and morphometric methods, the state of the osmoregulatory system at different stages in

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postembryogenesis has been analyzed in salmon juveniles with short (chum, pink salmon) and long (coho, sockeye, masu and Atlantic salmon) freshwater life periods.

The findings indicate that the morpho-functional formation of the effector and endocrine organs in these two ecological salmon groups occurs at a different rate in the freshwater period of life, but in both groups it correlates with the level of development of the osmotic homeostatic mechanism (as registered by the dynamics of variation in blood serum osomolarity in the process of juvenile adaptation to salt-water environment), with the degree of smoltification and with behavioral traits. The development of the osmotic homeostatic mechanism in the freshwater period of ontogenesis in the juveniles of migratory salmon species is the determining direction of the smoltification process.

In considering smoltification as a process of morpho-functional formation of the organism in the individual development of salmon fishes, which enables the transition of the juvenile to salt-water mode of life, the conclusion follows that the smoltification process is peculiar not only to salmon species in which the juveniles have a prolonged freshwater period of life, but also to salmon species in which the juveniles develop [only] for a short period in freshwater conditions.

The elucidation of the optimal environmental conditions required for the normal formation of the organism and favoring synchronicity of its interrelated component elements, is important for improving the biotechnology of artificial salmon culture.

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A POSSIBLE VARIANT OF GENOTYPIC SEX DETERMINATION IN SALMONID FISHES

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Numerous attempts at sex reversion in salmonid fishes /169* at post-zygotic stages by the most varied methods (hormonal preparations, temperature, illumination, feeding regimen) on the one hand demonstrate the possibility of substantially shifting the sex ratio, and on the other hand, by no means always lead to /170 unequivocal results, so that we may propose heterogeneity of sex genotypes for degree of resistance to various deviations from the adaptive norm.

On the basis of the tetraploidy of salmonid fishes, S.M. Konovalov (1960) has proposed a scheme of polychromosomal sex determination, in which xxxx and xxxy are female genotypes, while xxyy and xyyy are male ones. In adopting this scheme, we introduced the following hypothetical assumption - genotypes xxxx and xyyy are the most resistant to reversion and usually yield the appropriate sex phenotypes, while the intermediate genotypes, xxyy and xxxy, are able to reverse their phenotypic expression, depending on the strength and nature of the factors influencing them.

Table 1, which has been constructed on the Pennet lattice principle, shows the theoretically possible ratios of sex genotypes in offspring from various crossing variants. It is obvious that these ratios can vary depending on the frequency of formation of gametes of different types, especially in the splitting of a genotype such as xxyy.

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TABLE 1
Sex genotype ratio in offspring from various crossing variants.

самки / самцы	xxxx	xxxy	xxyy"
xyyy	I♀' : I♂,	I♀' :2♂, :I♂'	I♀' :3♂, :3♂
xxyy	I♀ :2♀' :I♂,	I♀ :3♀' :3♂, :I♂	I♀ :4♀' :6♂, :4♂'
xxxy„	I♀ :I♀'	I♀ :2♀' :I♂,	I♀ :3♀' :3♂, :I♂'

Key: 1 - females; 2 - males.

Note: ♀' ; ♂, are individuals with intermediate genotypes; xxxy„; xxyy" are genotypes with reverse phenotypic expression. The variants usual for natural populations are shown in the frame.

Donaldson and Hunter (1981), as evidence of the homogameticity of females, cite cases of obtaining 100% females from the crossing of regular females with reverted males. However, if all the genotypic females (phenotypic males) were nomogametic (xx), then the number of families with 100% female offspring should have approximated half of all the experimental families, but in practice their frequency does not exceed 20%, which is closer to the theoretical frequency of the stable female genotype which we determined - about 11%. /171

At times of depressions in the migratory part of the populations in sockeye and coho stocks, reproducing or foraging in mesotrophic lakes, an increase occurs in the ratio of dwarf males and jacks, which in some cases reaches 10:1 [sic!] (Kurenkov et al., 1982), which is also close to the value cited above.

On the whole, however, when the population is situated in conditions corresponding to the adaptive norm, the variant discussed ensures the maintenance of the equilibrium sex ratio.

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INFLUENCE OF FEEDING INTENSITY ON SEX RATIO IN JUVENILE O. NERKA

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The sex ratio in sockeye populations which have the dwarf /171* form, on the whole (taking the migratory form into consideration as well) is markedly shifted in favor of males and reaches 10:1 in some periods, which cannot be explained only by the selective detention in freshwater of individuals of the male sex, since a predominance of females in the downstream migration of juveniles and in the return of adults is usually slight, if one is observed at all.

The positive relationship between biomass of food zooplankton in the foraging body of water and the abundance of the dwarf form, previously discovered by E.M. Krokhin (1967), prompted us to conduct an experimental investigation on the influence of food objects and feeding intensity on the sex ratio in young of the year sockeye.

Larvae which had emerged from the redds in May were caught in the littoral of Dal'nee Lake in June and divided into three basic groups.

The first group (80 fish) was maintained in 7 aquariums in conditions of high zooplankton concentration (8,000-10,000 spec./L, mainly **Cyclop scutifer**) at a temperature of 12-14°C.

The second group (50 spec.) received approximately 12 times less plankton at the same temperatures.

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The third group was divided in turn into two parts: one part received artificial feed once a day, the other at hourly intervals at a temperature of about 9°C.

At the end of August, the fish were dissected to determine sex. In the first group, the sex ratio was markedly shifted in favor of males in all 7 cases in proportions of 6:1 to 11:1 (cf. 7.3:1), in the second, 1.8:1. /172

In the third group, the fish which were fed once a day showed a ratio of 1:1, those fed hourly, 1.2:1.

In the shore zone of the lake in the same period, the sex ratio in young of the year whose ration consisted mainly of chironomid larvae and imagoes, as well as single benthopelagic crustaceans, practically approached the equilibrium ratio - 1.1:1.

Thus, excessive feeding on plankton has a considerable influence on sex differentiation in sockeye, comparable to that of androgenous preparations, which cause sex reversion. The mechanism of this phenomenon is still unclear, but we may make the following assumptions: the high energy content of zooplankton by comparison with other food objects, in the case of excessive consumption, causes the accumulation in the juvenile organism of macroergic compounds which raise the level of somatotropin synthesis, in turn indirectly stimulating the production of androgenous steroids. Both of these processes are accompanied by the accumulation in the organism of calcium, magnesium, chlorine and other ions, which can hinder considerably the normal development of the presmoltification processes, and sometimes probably completely inhibit them. Another possibility is the direct action on the juvenile endocrine system of androgenous hormones, the content of which is rather large in crustaceans.

Since the main food of generatively lake sockeye is zooplankton, which is able to rapidly increase its biomass in mesotrophic waters when the abundance of foraging juveniles is lowered, the exceptionally marked shift in the sex ratio in favor of males, which is not usually observed in other salmons and which is most often expressed in an increase in the ratio of jacks and modification dwarfs, can be explained in terms of the ideas presented above.

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MORPHOLOGICAL AND BIOCHEMICAL CHARACTERISTICS OF ATLANTIC SALMON DURING THE PERIOD OF SPAWNING MIGRATION

By T.K. Lebskaya, L.V. Pashkova, L.L. Konstantinova and V.S. Tuchkov of the Polar Scientific Research Institute of Marine Fisheries and Oceanography im. R.M. Knipovich (Murmansk), and Leningrad State University im. Zhdanov

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A study has been done of a complex of biological and biochemical indicators in 52 Atlantic salmon specimens from the Tuloma R. during the spawning migration. Evaluation of external morphological changes due to physiological restructurings in the maturing fish was done by V.G. Martynov's scale of post-spawning condition.

The Schmidt's length of the study fish varied from 46 to 75 cm, mass from 1300 to 7560 g.

It has been established that muscle tissue protein content in Atlantic salmon does not exhibit differences at different post-spawning stages and is 20-22%. Fatness varies: from 2.69 to 15.28 for stage 0; from 2.63 to 9.62 for stage I, and from 1.1 to 6.43% for stages II and III.

No correlation is observed between fatness and sex, size or weight. Three groups of muscle fat content can be distinguished: low fat (up to 5%), medium fat (from 5 to 6%) and high fat (from 8 to 15%). Specimens with high and average fatness predominate in Atlantic salmon in post-spawning stages 0 and 1, low-fat individuals in stages II and III.

Expression of external morphological changes is in accordance with the extent of development of sexual products.

The muscle tissue protein of Atlantic salmon at different post-spawning stages contains all the essential amino acids in a ratio close to the standard protein recommended by the FAO/WHO committee and does not depend on the post-spawning stage.

Electron-microscope studies of the skeletal musculature have shown that there is a reduction in glycogen and fatty drops between myofibrillae in the transition from post-spawning stages 0 to III.

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ADAPTATION OF JUVENILE ATLANTIC SALMON TO SALT WATER IN THE BARENTS SEA

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Sciences, Dal'nie Zelentsy

The transfer of juveniles to salt water is one of the /177* critical moments in the commercial culture of Atlantic salmon in the Barents Sea, since of all the seas in the USSR inhabited by the Atlantic salmon, this sea is the saltiest, while the quality of juveniles reared by the fish hatcheries of the North is low. In order to evaluate the possibility of commercial salmon farming in the Barents Sea, semi-commercial farming of Atlantic salmon and rainbow trout in salt water was begun in Dal'nie Zelentsy Bay in the summer of 1987. The work was done on juveniles taken from fish hatcheries without any sort of preliminary selection, using standard hatchery equipment and feeds (RGM [Expansion unavailable. -Transl.] and feed krill). The object was to obtain not only fisheries but also economic assessments of the effectiveness of commercial salmon farming in the Northern basin.

The aim of the first stage of the work was the adaptation of the juveniles to salt water. The work was done at a shoreside pool base. One thousand Atlantic salmon yearlings weighing 17.2±0.5 g was shipped from the Verkhnyaya Tuloma hatchery. By external characters, the fish were smolts, although not one of them was a true smolt, since when 50 of this batch were abruptly transferred to salt water (34‰), half of them lived less than 30 h, while the maximal survival time was 9 days.

After the wastage due to transportation had terminated, the

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salinity of the water in the basin with Atlantic salmon was raised to 15‰, and then increased daily by 2‰ until a salinity of 34‰ was reached. After two days of residence, the juveniles were transferred to a marine tank. Adaptation occurred at a water temperature of 7-9°C. The total wastage in adaptation was 11.5%. The adaptation process can be divided into three periods in terms of wastage intensity. The average-daily waste was 3.3% in the 15-23% salinity range, 7.8% at 23-34‰, and 10.7% per day at 33-35‰.

As is known, the survival rate of fish when transferred to salt water is directly related to their dimensions. A similar relationship was observed in the juveniles who died after an abrupt transfer to 34‰. However, in the case of gradual adaptation, the relationship between fish size and survival was more complex. It proved possible to distinguish 4 periods which /173 were characterized by the fact that the dying juveniles were somewhat smaller at the beginning and end of each period than in the middle. The average weight of waste was smaller than the average weight of fish before and after adaptation, that is, it was the small fish that were subject to elimination. The weight of Atlantic salmon after adaptation was 22.5 ± 1.7 g.

Adaptation of rainbow trout (average weight 150 g) was done in three variants. The initial salinity was 15‰, which was increased by 5‰, 10‰ and 20‰ per day. The wastage in adaptation was negligible (3%) and did not differ reliably in the different experimental variants.

Thus the first stage in the semi-commercial experiment showed that the Atlantic salmon and rainbow trout juveniles that are cultivated today at the hatcheries in Murmansk Oblast are quite capable of being adapted for farming in tanks in the Barents Sea in a sufficiently short time and with a sufficiently high survival rate. The most difficult problem for Barents Sea salmon farming will apparently be the wintering of commercial fish.

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CHARACTERISTICS OF INITIAL STAGES IN GAMETOGENESIS OF O. KETA AND O. GORBUSCHA IN THE PROCESS OF INCUBATION OF EMBRYOS AND REARING OF FINGERLINGS AT VARIOUS TEMPERATURES

By N.A. Lukina, T.N. Svimonishvili and Yu.N. Gorodilov

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We studied gametogenesis in two species of Pacific salmon /181* of the genus **Oncorhynchus**: in chum during the embryonal-larval period and during the rearing of juveniles in freshwater to a maximum of 3-4 g at three different constant temperatures (5.0, 8.4 and 11.5°C) and in pink salmon during the embryonal-larval period, without further growth, in temperature regimes of 6.0 and 8.9°C.

One should note the earlier and more dynamic, compared to chum, development of the gametes and gonads in pink salmon, in which sexual cells at the zygotene-diplotene stage of the meiosis prophase are already detected at hatching. In the present work, /182 we have investigated in detail the gonad development stage which G.M. Persov has defined (1966) by the occurrence of sex inversion in pink salmon, that is, a phenomenon the essence of which is that only oocytes in the early stages of the meiosis prophase are initially present in the gonads of all larvae, while later, in some larvae, the oocytes degenerate and a population of male gametes is formed by the proliferation of undifferentiated gonia which are present in the gonads. Data have also been obtained on the developmental chronology of different stages of the gametes and gonads in pink salmon when larvae are maintained at different temperatures.

*The numbers in the right-hand margin indicate the corresponding pages in the original. - Transl.

In chum, at the time of hatching of embryos, the gametes are still in indifferent state at all study temperatures. Signs of sexual differentiation are noted in the early larval stage with the appearance of oocytes in the meiosis prophase, while oocytes in the initial stage of cytoplasmic growth are found in the anlages of the gonads on the transition of the larvae to mixed feeding. Unlike the pink salmon, sex differentiation in chum is observed immediately after the indifferent period. Retention of juveniles in freshwater, as well as accelerated development and growth at higher temperatures, do not cause degenerative phenomena in the oocytes, while their further differentiation and growth are related not to the size and mass of the fry, but to their biological age. Only spermatogonia were observed in the testes during the entire growth period. A chronological table, expressed in relative time units, of the stages of gamete differentiation in the development of individuals of the two study species has been prepared.

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A STUDY OF INTRA- AND INTERPOPULATION DIFFERENTIATION IN ATLANTIC SALMON SALMO SALAR L., WITH THE AID OF THE MAIN COMPONENTS METHOD

By A.N. Lyashenko
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To investigate species structure in ichthyology, in /184*
addition to methods of physiology, ethology, karyology and biochemical genetics, morphometric measurements, which enable us to identify populations and intrapopulation groupings in fish with sufficient reliability (Ihssen **et al.**, 1981), are also used. The study of the results of morphometric measurements which as a rule involve dozens of characters requires the use of multivariate mathematical, including component, analysis. Here a multitude of input values of quantitative parameters is reduced to a small number of complexes of correlated characters. The necessity for using analysis of a complex of characters follows from the fact that the effect of any factor is felt not on a particular character, but involves their aggregates (Zhivotovskii, 1984).

The aim of our investigation was to study by means of the main components method (Anderson, 1963; Kendall, Stewart, 1976) the intra- and interpopulation differentiation of the Atlantic salmon populations of a number of rivers in the White Sea basin. The material was collected in 1984-86 in the Khlebnaya, Byalitsa, Umba rivers, as well as in the Ukka, a second order tributary of the Umba R. The fish were caught in June-July, during the catadromous /185
migration. Measurements (of 24 characters) were done by the conventional system (Pravdyn, 1966). The total number of fish examined was about 500 spec.

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The results of analysis showed that in the study populations, all the characters fit in the first main component. They are characterized by large weight factors and positive signs. The first main component, then, can be interpreted as a general one. It "picks up" from 70 to 90% of the variability of input characters. The characters which determine fin dimensions make up the second and third main components. These components account for 4 to 10% of variability.

Differentiation between the study populations has been found with respect to fin dimensions and exterior characters, determining fin topography. At the same time, differences in characters characterizing body height and head proportions were found to be negligible. Besides interpopulation differences, intrapopulation differences have also been established by the same character complexes - on comparison of juveniles of different ages in each study population, and on comparison of juveniles from the Umba and the Ukka. These differences are indicative of a complex spatial and temporal structure of Atlantic salmon populations. As component analysis showed, these differences may be related both to a difference in the level of variability in quantitative characters in different age classes, and to differences in the nature of correlations between the study characters in the process of their formation.

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MOLECULAR HYBRIDIZATION OF DNA AS ONE OF THE METHODS OF DIFFERENTIATION OF COMMERCIAL STOCKS OF PACIFIC SALMONS

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A scheme of relationships within the genus **Oncorhynchus** /186* has been constructed using the method of molecular hybridization of DNA and modifications of it.

The species within the genus are broken down into three groups: 1) chinook, 2) Coho, 3) Masu, pink salmon, sockeye and chum. The masu has preserved more ancestral traits than the other species. In addition, it is also genetically closer than all other Pacific salmon to the "mikizha" - **Salmo mykiss** Walb.

Experiments in the hybridization of the DNA of the 4 coho populations of the Sea of Okhotsk coast and Bering I. showed that the Yana, Gizhiga and Kukhtui populations are genetically closest to each other, while the coho from the Sarannaya R. (Bering I.) /187 is quite far removed. Heterogeneity of DNA during the spawning run has been found in the coho from the Bol'shaya R. (W. Kamchatka). However, intrapopulation does not exceed interpopulation variance by this character.

The results of the molecular hybridization of the DNA of 7 Amur populations of summer and fall chum forms suggest a very high integration of the genofonds of the populations of the spawning rivers in the lower reaches of the Amur R., which can be treated as a single population system. From the chum going to spawn in the Taui R. (continental coast of the Sea of Okhotsk), fish have been

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singled out going into the Kava and Chelomdzha rivers that differ from each other genetically. An assessment has been done of genetic heterogeneity of a marine chum sample taken at foraging and migration sites in the Bering Sea. It has been established that at least 3 groups are present in the salt-water sample: those close to the Anadyr chum, those close to the chum of the Vyvenka R. and those not having an analog in river samples. The bulk of the chum caught in the Korfa-Karaginskii region is evidently of Anadyr origin. A considerable genetic closeness of the Penzhina to the Anadyr and Vyvenka chum has been found, which indicates the existence in the Quaternary of a connection between the chum of these stocks during the floodings of the Paropol'skii dol by marine transgressions. It has been noted that the homology in the repeating DNA sequences in chum, and perhaps in other Far Eastern salmon as well, is a rather stable character which is traced in populations which have not had gene exchange for more three thousand generations.

The possibility has been shown in principle of using the method to determine the birthplaces of salmon from single specimens caught at sea, and for mapping foraging and migration regions.

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SOME RESULTS OF AND PROSPECTS FOR THE USE OF SALMON GONADOTROPHIN TO STIMULATE MATURATION OF PACIFIC SALMONS

By A.A. Maksimovich, V.N. Polyakov, V.v. Plyusnin, M.V. Smirnov, I.V. Kalina, V.V.Sheiko and Li Kie of the Institute of the Biology of the Sea of the Far Eastern Scientific Center of the Academy of Sciences of the USSR, Vladivostok.

As is known, whole hypophysial preparations of different /189*
fish species are widely used at the present time in fish culture to stimulate the maturation of spawners. However, the heterogeneity of preparations used, which contain in addition to gonadotrophin (GTH), a complex of other hormones and neuropeptides, and the lack of standard gonadotrophic activity of this material makes all the more acute the need for creating purified standardized GTH preparations.

Together with workers of the Institute of Biology of the Academy of Sciences of the Latvian SSR, we have obtained and tested experimentally in fish GT hormones extracted from the hypophyses of male and female pink salmon (Zenkevich **et al.**, 1985). The GTH was purified by gel filtration and ion-exchange chromatography, as well as by binding on concanavalin. The biological activity of different GTH fractions was tested on three groups of Pacific salmons: 1) young of the year chum (males and females at the first stage of maturation of the gonads (SMG I), 2) dwarf masu males (SMG IV) and 3) adult prespawning pink salmon males and females (SMG IV). The GTH was administered intraperitoneally, the dose in all experiments being 250 mcg/kg of mass.

The following results were obtained. After 39 days of weekly GTH injections, the young of the year chum males reached SMG III.

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In natural conditions this usually occurs in chum at the age of 3+ or 4+. The development of the ovaries in females was advanced from the 2nd to the 3rd stage in the protoplasmic growth phase. The gonadosomatic index was increased by comparison with the control by 3.9 times in females and 10 times in males.

GTH injections to dwarf masu males and adult pink salmon males and females were done as follows. The first 20% of the dose was administered intraperitoneally and the rest 6 h later, also intraperitoneally. Twenty two - twenty four hours after the first injection, all the fish were in ripe condition (SMG V), and their sexual products were suitable for fertilization.

The successful application of salmon GTH for experimental /190
purposes, as well as the favorable prospects for their utilization in fish culture enable us to formulate a number of priority tasks. There is an obvious need to organize the semicommercial production of salmon GTH and to create GTH preparations of standard activity. Studies are needed to establish the limits of species-specificity of salmon GTH. Improvement of the biotechnology of hormonal stimulation and the search for substances which enhance GTH action will also be an important part of future work. These specific goals, which are of first importance for fish breeding practice, will on the other hand contribute topicality to theoretical studies of the hormonal mechanisms of reproduction in fishes.

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MORPHOGENETIC CHARACTERISTICS OF HYBRIDS OF COREGONUS PIDSCHIAN PIDSCHIAN AND C. AUTMNALIS MIGRATORIUS IN LAKE BAIKAL

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The existence of natural hybrids in Lake Baikal from the /192* crossing of the Ob whitefish ("pizhyan") and the Baikal omul have been known for a long time. Morphologically by most characters the hybrids occupy an intermediate position from the parental pairs (Skryabin, 1969).

In 1984, in the Verkhnyaya Angara R., we obtained hybrids by artificial means. The hybrid juveniles were reared at the Burduguzsk fish hatchery; their behavior, growth and morphological characteristics were studied. These results, as well as the common spawning grounds and close spawning times of the Ob whitefish and the Baikal omul indicate the possibility of mass appearance of hybrids in natural conditions. Further study of the natural populations revealed that in the winter of 1986 in the northern Baikal shallows, the abundance of all hybrid juveniles (1+ - 3+) in eight 200-300 fish samples varied from 10 to 70% of the total abundance of Ob whitefish juveniles caught.

The samples broke down well into four groups of fish with 19-23, 23-25, 26-29 and 30-33 gill rakers. The first group comprises the juveniles of the Ob whitefish, the fourth, first generation hybrids, the third and second, recurrent hybrids. Note that there are 39-45 gill rakers in the Northern Baikal omul population.

*The numbers in the right-hand margin indicate the corresponding pages in the original. - Transl.

Analysis of inheritance of the number of gill rakers showed that for this trait, the recurrent hybrids have intermediate values from the initial forms and spawn predominantly with the Ob whitefish.

The prolonged existence of hybrid Ob whitefish populations is known (Bikkinin, 1978; Reshetnikov, 1980). In contemporary conditions in Lake Baikal, hybrids are constantly appearing and disappearing, dissolving in the parental forms. It is natural to assume an influence of hybridization on the morphological characters of the Ob whitefish, whose abundance is very small. Thus, the pizhyan of the Angara R. has an average of 20.4 gill rakers (Podlesnyi, 1953), while in Lake Baikal, the number varies /193 from 21 to 23 gill rakers in different populations.

The necessity arises for a deeper study of the genetic changes in hybrids and in the Ob whitefish. We used the method of electrophoresis in polyacrylamide gel. We studied 17 protein systems encoded by 30-31 gene loci, of which 6 are polymorphous: α-glycerophosphate dehydrogenase, sorbitol dehydrogenase, malate dehydrogenase, 6-phophogluconate dehydrogenase, fumorase, esterase. Reliable differences between the observed hybrids were found for at least 4 loci: Mdh -3,4; 6-Pgd-1, Sdh-1; Est-1. A correspondence of observed to theoretical frequencies was observed for all polymorphous loci, in accordance with the proposed inheritance scheme.

In two systems (MDH and 6-PGD), the initial forms - the whitefish and omul - are characterized by diametrically opposite distribution of allele frequencies: the frequency of the Mdh-$3,4^{78}$ ("slow") allele is 0.63 and 0.05, respectively, the frequency of the 6-Pgd-1^{78} ("slow") allele is 0.89 and 0.4. In first generation hybrids, the contribution of the parents is about equal; an increase in the dose of genetic material of the Ob whitefish is observed in recurrent hybrids.

In the majority of cases, the dose effect of the parental alleles in the hybrid forms follows the proposed genotype, but for Est-1 and Sdh-1, several specimens have been found in which it is violated.

Thus, in hybrids of the Ob whitefish and Baikal omul, the summary parental traits predominate; hybrid products can be formed (in generation F_1) and traits of one of the parents can appear (in recurrent hybrids).

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POPULATION STRUCTURE OF O. GORBUSCHA OF SOUTHERN PART OF SAKHALIN I.

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In 1987, by the method of electrophoresis in polyacrylamide gel, we investigated the structure of pink salmon populations from the basin of the Ochepukha, Dolinka, Tarantai and Bol'shoi Takoi rivers. One sample was taken in Aniva Bay not from the mouth of the Lyutoga R. Each sample consisted of 100 pink salmon specimens. Two thousand four hundred adults were taken and analyzed in the Ochepukha R. and its tributaries, 400 in the Dolinka R., and 100 each in the Tarantai and Bol'shoi Takoi rivers and in Aniva Bay. The gene frequencies of three polymorphous enzyme systems have been calculated: α-glycerophosphate dehydrogenase, 6-phosphogluconate dehydrogenase, malate dehydrogenase. We used quantitative characters - number of gill rakers on the first left arch, length of males and females, as well as an external qualitative character - spotting of the dorsal part of the body.

Statistically reliable differences have been found between pink salmon from different rivers both for qualitative and quantitative characters. The pink salmon from Aniva Bay differed from all other samples in its large size and high frequency of the allele of 6-phosphogluconate dehydrogenase, and had a larger number of gill rakers than fish from other regions. Samples with similar characteristics have not been found in any of the study rivers. This pink salmon evidently belonged to some other stock and was on the migration route to its spawning grounds.

In the basin of the Ochepukha R., the variation in the study indices were traced throughout the course of the spawning run from July 24 to September 24. It turned out that fish of different run times differ reliably. Similar findings have also been obtained for the Dolinka R.

Reliable differences have been found between samples from the main channel of the Ochepukha R. and its tributaries.

There is no doubt that the pink salmon of the southern part of Sakhalin I. has become differentiated into the populations of the different rivers, in which there exist subpopulations. There is also a division by time of spawning run into seasonal groupings.

The findings on significant differences between samples from the tributaries of the same river suggest rather pronounced homing in the pink salmon.

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INHERITANCE OF TRUNK LENGTH, BODY MASS AND LEVEL OF PHOSPHATASE ACTIVITY IN O. GORBUSCHA

By E.A. Matsak and L.V. Bogdanov
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In order to study the level of specific phosphatase activity /200* (in homogenates of muscles at pH 8.3) as a possible selection trait in breeding spawners on September 4 1986 at the "Lesnoi" fish hatchery (southeastern Sakhalin), 7 batches of eggs from spawners of different combinations of size-weight characteristics and level of phosphatase activity (LPA) were placed in incubation.

Trunk length (L) and body mass (W) of males were respectively from 40 to 58.5 cm and from 640 to 1950 g. The same indices for females were from 40 to 50.5 cm and from 680 to 1570 g.

The coefficient of correlation between L and LPA for a random sample of 110 spawners of both sexes was: for males, a reliable value of 0.34 (negative relationship), for females an unreliable value of 0.09 (a similar picture was also observed in the "Lesnoi" area in 1985 as well; in addition, a negative correlation between trunk length and $LPA_{9.3}$ in sperm plasma was found in chum salmon males caught in September 1984 in southwestern Sakhalin.

Average L, W, and LPA values were determined for fingerlings at age 2.5 months from each redd.

The number of fingerlings in redds fluctuated from 70 to 100.

*The numbers in the right-hand margin indicate the corresponding pages in the original. - Transl.

The following coefficients of correlation were calculated between the values of the characters of spawners and the average values of the characters of progeny (the parental characters are denoted by the index P, progeny f):

P	$L_p - L_f$	$w_p - w_f$	L_p - УФА	w_p - УФА	УФА - $\bar{s}_f$	УФА - L_f	УФА - w_f
	-0,26	-0,40	0,71	0,75	-0,27	0,55	0,33
	0,36	0,60	-0,56	-0,69	0,13	0,78	0,70
p	0,03	0,15	0,32	0,23	-0,08	0,77	0,59

1-LPA

The correlation found between the size and weight of spawners and progeny does not fit the usual concepts about the intermediate nature of inheritance of these characters and the approximately equal contribution of both parents to their formation in offspring: the coefficients of correlation were reliably negative for males (to put it simply: large males give small offspring, and vice vera) and were reliably positive for females.

The length and mass of males disclosed a positive association /201 with LPA of progeny, while the same characters in females showed a negative one.

The coefficient of correlation of the LPA of male spawners and offspring had a negative value but for females and offspring was positive with a low absolute value.

High coefficients of correlation characterized the relationship of LPA of spawners, especially females, with the average length and mass of progeny (in other words, the higher the LPA in spawners, the higher the size-weight characteristics of progeny at 2.5 months of age).

On the basis of the above and taking into consideration that a marked negative relationship between body size and LPA has been found in male spawners, we may conclude that the largest offspring at 2.5 months of age is obtained from the crossing of relatively small males with large females.

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MOLECULAR GENETICS AND SYSTEMATICS OF SALMONIDS

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As is known, many problems in systematics to this time /201* remain the subject of discussion. This can be explained by the fact that the widely used methods of classical systematics, which are based on the analysis of phenetic characters (morphometric, osteological, immunological, biochemical, including analysis of protein electromorphs) are found to be to be inadequate for the construction of a natural system. The group of salmonids is a good example of the limited possibilities of phenetic systematics, since it is precisely here that the phenomena of homological variability, polymorphism and ontogenetic variability are widely represented. The ratio of the number of recently described synonyms to the number of "good" species can serve as the criterion of the unfinished state of a system: this indicator is very high in salmonids and has a tendency to grow.

Analysis of genomes by the methods of molecular genetics can offer substantial help to taxonomy. For a number of reasons, homologies in the structure of the genome better /202 reflect affinity than phenetic homologies. In addition, they can be measured by an objective number (I underline that the so-called "numerical taxonomy", including the estimation of genetic distances, gives only the appearance of quantitative assessment).

A real revolution in molecular-genetic methods has occurred in recent years. Their resolving power has increased enormously; we can now confidently discriminate and quantitatively determine

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the degree of divergence not only of genera and species, but even of intraspecies forms, and estimate the scale of interpopulation, intrapopulation and even individual variability (so-called "molecular fingerprints", by which one can distinguish the genomes of individual specimens).

From the rich and ever expanding arsenal of molecular genetic methods, we can distinguish the following groups of approaches in terms of resolution:

1) Analysis of relationships between close genera and species within the genus. The most promising is the method of molecular hybridization with subsequent analysis of the thermostability of hybrid duplexes and restriction analysis of the replica-enriched DNA fraction. By these methods, a number of findings has already been obtained on the systematics of the salmonid fishes enabling a new evaluation of their relationships.

2) Analysis of intraspecies variability. Molecular hybridization again offers promise, as well as regular and blot-hybridization using molecular probes - cloned or synthetic DNA sequences, for large-scale studies.

3) Analysis of sexual dimorphism in genome structure and individual variability (blot-hybridization using cloned high replicas and minisatellites, sequencing).

The difficulty and high cost of experiments can not be used as arguments against the use of molecular-genetic methods, since their accessibility is continuously increasing from year to year. We may say that by the year 2000, molecular genetic methods will become the main tool of systematics at all levels of construction of the natural system.

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POLYMORPHISM OF LIVER ESTERASE IN ONCORHYNCHUS NERKA WALB.

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Polymorphous nonspecific liver esterase in sockeye is /212*
represented on electrophoregrams by three variants. Two variants consist of two bands of enzymatic activity each. The electrophoretic mobility of the "slow" and "fast" bands in one variant is identically altered with respect to the mobility of the corresponding bands of the second variant. The third variant contains all four bands. Analysis of inheritance of electrophoretic variants of esterase has been done in the offspring of paired crossings. The crossings were done in sockeye spawners going into Kuril'skoe, Azabach'e and Dal'nee lakes (Kamchatka Peninsula) to spawn. We analyzed 1856 fingerlings from 13 parental pairs. The juveniles in two crossings consisted of individuals containing four bands of esterase activity. In other crossings, a splitting of offspring occurred into two or three phenotypic classes, in which inheritance turned out to be linked to sex. The sex ratio in the progeny from different parental pairs did not differ reliably from 1:1. In the families with splitting into two classes, the offspring was represented by individuals with four band esterase spectrum and individuals with one of the two band spectral variants in a 1:1 ratio. In the families where /213
splitting into three classes occurred, the juveniles consisted of individuals with both types of two band spectra and individuals containing the four bands. The ratio of two band to four band to individuals with the second two band variant was 1:2:1. The results of genetic analysis therefore suggest that the observed variability in electrophoretic esterase variants is controlled by

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a single locus with two codominant alleles. The products of the allele genes are represented on electrophoregrams by two bands of enzymatic activity. Inheritance of alleles occurs by a type of sex linkage.

In the pink salmon, a species which is systematically close to the sockeye, an autosomal type of inheritance of electrophoretic variants has been described (Muske, at the press). The different type of inheritance of alleles of the homologous locus in close salmon species is apparently due to the existence in this group of fishes of multiple sex chromosomes and reflects, so we surmise, interspecies differences in the sex determining mechanism in salmons of the genus **Oncorhyncus**.

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ON THE PROBLEM OF ORIGIN OF SEVAN TROUT, SALMO ISCHCHAN KESSLER: A POPULATION GENETICS APPROACH

By A.G. Osinov,
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The Sevan trout is an endemic species whose range is strictly /228* confined to the lake itself and its tributaries. The level of ecological differentiation of its forms is so substantial that they were previously described (Kessler, 1877; Yakovlev, 1888) as independent species. Only after careful morphobiological analysis were the "gegarkuni", the winter "bakhtak" (ishchan), the "bodzhak" and a fourth form - the summer "bakhtak" (ishchan), described for the first time, once again (see Kavraiskii, 1896) brought into the framework of a single species (Fortunatov, 1927). A river form of /229 the gegarkuni - the "alabalakh" was later distinguished separately (Vladimirov, 1944). Some authors consider that the alabalakh is a relict form of the brook form of sea trout (Dadikyan, 1971; Rukhkyan, 1984).

While the fact itself of the origin of the Sevan trout from the brook trout (sea trout) is accepted by all investigators, the question as to the time, manner and sequence of differentiation of its various races gives rise to different opinions. Thus, according to V.I. Vladimirov (1944), the origin of the gegarkuni and the winter bakhtak is associated with two periods of isolation of the lake from its tributaries and settlement of the brook trout in the lake accordingly in stages. According to M.G. Dadikyan (1971) and E.A. Dorofeeva and R.G. Rukhkyan (1982), the origin of all the races, although in different sequence, is associated only with ecological factors, that is, their differentiation occurred in sympatric conditions. The majority of authors associate the beginning of the process of differentiation of the Sevan trout with the onset of the Wurm glaciation, and its completion eve with the postglacial period.

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To analyze the level of genetic variability, we studied 12 enzyme systems encoded in total by 29 gene loci. In all, 672 sea trout, 512 Sevan trout (87 gegarkuni, 165 summer ishchan, 81 bodzhak, 100 alabalakh, 79 Issyk-Kul' gegarkuni) specimens were analyzed.

Against the background of a rather high level of genetic variability, which is typical of all the sea trout populations ($H = 0.52 - 0.120$; $P = 0.179 - 0.310$), the genetic impoverishment of the Sevan trout is obvious ($H = 0.000 - 0.002$; $P = 0.000 - 0.034$). Moreover, in all races at all loci, the same alleles are fixed or close to fixation. These two facts suggest (Osinov, 1984) that the loss of genetic diversity most likely occurred before the start of the ecological differentiation of the Sevan trout and is evidently associated with the initial stage of its individuation. In fact, when we take into consideration that the last insurmountable obstacle to the penetration into the lake of new groups of brook trout from the rivers of the Araks basin became the Varsersk waterfall on the Razan R., whose formation is dated to the post-Wurm period (Vardanyants, 1948), we may draw the following conclusions.

In the means of its formation, the Sevan trout is only a geographic isolate of the sea trout. Its relatively recent individuation is also confirmed by the low level of their genetic differentiation ($P_{Nei} = 0.007 - 0.042$). The ecological differentiation of the Sevan trout began only after its individuation from the sea trout and occurred in conditions of sympatry. It is not excluded that the species impoverishment /230
of the ichthyofauna of Lake Sevan (only three as against 16 species living in the rivers of the Araks basin {Dadikyan, 1969}) and the loss of genetic diversity in the Sevan trout are the result of the same causes. In particular, it is not excluded that this is the result of a marked deterioration in living conditions as the result of the powerful volcanic eruptions in the basin of the lake which took place even in the Anthropogen (Milanovskii, 1957).

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GENETIC DIFFERENTIATION OF POPULATIONS OF MIGRATORY TROUT S. TRUTTA L. ON THE COAST OF ESTONIA

By T.K. Paaver
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Rational utilization and conservation of migratory trout /233* stocks can not be achieved without taking into account the population structure of this species. In Estonia, the trout ascends for spawning into small rivers partitioned by dams not far from the sea. The appearance of several isolated populations within a river is not likely and the stock of each river can be treated as one population. The aim of our work was to assess the degree of differentiation of the trout population in the rivers of Estonia by the methods of biochemical genetics.

Samples from 17 Estonian rivers (falling into the Gulf of Finland and Gulf of Riga and into island bays) were analyzed. Eight enzymes, determined by 20 loci, were investigated by the method of electrophoresis. Five enzymes (7 loci) - AAT, AGP, LDH, MDH, KA were found to be polymorphous.

The genetic distances after Nei turned out to be small, 0-0.009. The homogeneity test showed the heterogeneity of the entire sampling of Estonian trout, although homogeneity in some loci was observed in some regions. Evaluation of heterozygosity by [Text illegible. -Transl.] criterion showed that 94% of the genetic variability of the Estonian trout is due to intrapopulation variability.

The genetic differences between trout populations within Estonia were negligible and were comparable with the heterogeneity

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detected in the analysis of isolated populations of freshwater trout or migratory trout forms inhabiting different sea basins. /234 The cause of this is probably genetic exchange between trout populations on the Estonian coast. Some differentiation is nevertheless observed between population groups of different regions (Gulf of Finland, Saaremaa I.).

The genetic differentiation of the migratory trout population in Estonia is poorly expressed due to disturbances in homing and the activity of fish hatcheries.

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REACTIONS OF CULTURED JUVENILE ATLANTIC SALMON TO SALINITY STIMULI

By I.D. Pavlov and N.V. Troshichev

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Using a special apparatus, consisting of two equal corridors /235* joined by a common compartment, we studied the effect of different salinity of the water on the behavior of Atlantic salmon two-year-olds of the Knyazhegubsk fish hatchery in the parr (weight 9.5±1.4 g) and silver parr 3 (weight 18.0±4.2 g) stages. The experiments were done on groups of fish at the same stage of maturity (30 specimens each), which had adapted to fresh or subsaline (3.5‰) water. We evaluated the reactions of the fish to a salinity of the water of 3.5, 7.5 and 15‰ on the basis of their movement and distribution in the compartment (movement to or away from the source of saline stimulus). We created a definite salinity with dissolved dry sea salt; concentration was calculated by the /236 volumetric method.

It has been shown that 87% of silver parr 3's adapted to freshwater, exhibited a distinct positive reaction to water with a salinity of 3.5‰. In this case, the fish moved around the compartment to the zone of influence of the saline stimulus, remaining in it until its use was stopped. The latent periods of the reactions did not exceed 15 s. Water with a salinity of 7.5‰ caused a positive reaction in only 23% of freshwater adapted silver parr 3's; the remainder showed an avoidance reaction. Virtually all the fish of this group avoided waters with a salinity of 15‰. In Atlantic salmon adapted to subsaline water, the positive saline selectivity proved to be considerably higher: more than 50% of

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silver parr 3's preferred water with a salinity of 7.5‰ and 35% preferred water with a salinity of 15‰. No more than 15 days residence in subsasline water (at a temperature of 7-9°) was required by silver parr 3's in order to manifest reliable differences in behavioral reactions to saline stimuli by comparison with freshwater-adapted fish. The Table shows the influence of different salinity of the water on the behavior of cultured Atlantic salmon juveniles.

Солёность воды, в ‰ 1	Распределение в отсеке установки, % 2	
	пестряток 3	серебристых пестряток 3 4
Фон (пресная) 5	100	100
0,23	111	100
0,46	88	116
3,5	78	121
7,5	80	129
15,0	63	132
34,0	9	84

Key: 1 - salinity of water, ‰; 2 - distribution in compartment, %; 3 - parr; 4 - silver parr 3's; 5 - background (freshwater).

The transfer of subsaline-water acclimatized groups to freshwater (at a temperature of 10-13°) resulted in a loss of positive reactions to a salinity of 7.5-15‰ in 3-5 d.

Differences have been found in the reactions of parr and silver parr 3's to the same salinity of the water (see Table; the number of fish situated in the "working" half of the compartment at the time of arrival there of the saline solution has been taken as 100%). Avoidance reactions to water with a salinity of more than 0-23‰ predominated in Atlantic salmon in the parr stage, the number of negative reactions increasing directly with concentration. Silver parr 3's gave preference to subsaline water, but avoided a salinity of 34‰. /237

Maintenance of silver parr in water with a salinity of 3.5-7.0‰ facilitates an acceleration of transformation of physiological mechanisms of preparation for the saltwater period of life. Differences in reactions to saline stimuli in parr and silver parr can be an additional criterion of preparedness of Atlantic salmon juveniles for downstream migration and can be used at hatcheries for the differentiated release of fishes.

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A STUDY OF THE REACTION OF MACROZOOBENTHOS TO THE EGGS OF THE SYAMOZERO WHITEFISH (C. LAVARETUS EXILIS) IN NATURAL CONDITIONS

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In connection with the considerable reduction in the abundance /237* of the Syamozero whitefish (southern Karelia), an attempt has been made to determine the possibility that eggs are consumed by benthic invertebrates at spawning grounds. For this purpose, we used a "device for observation of the development of the eggs of lake fish in natural conditions"(Pavlovskii, Sterligova, 1983).

The device was set up in the whitefish spawning grounds at a depth of 2.5 - 2.7 m in October and was removed in March (1982-83 and 1983-84) by scuba divers. As a substrate in the experiments, lake sand and gravel which had been washed of organic matter in saturated salt solution was used. We evaluated the settlement by invertebrates of substrate without eggs and substrate with fertilized whitefish eggs (with an egg sowing density of 625 eggs/m^2 and 250 eggs/m^2). To exclude consumption by fish, the soil with eggs was covered with lids of 5 mm netting after the device had been set up on the spawning grounds. During the period of observations in the fall, macrozoobenthos samples were taken with an Ekman-Berdzh (grab area 1/44 m^2) and a DAK-250 (grab area 1/40 m^2) dredges.

The results of the dredge samples showed 4 groups of invertebrates: chironomid and mayfly larvae, oligochaetes and

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nematodes. The average abundance of organisms was 4840 spec./m^2 in October, 1982 and 2370 spec./m^2 in October 1983.

The population of the substrate with eggs was represented by /238
8 animal groups: chironomid, mayfly, stonefly and caddis-fly larvae, molluscs, oligochaetes, nematodes and water sowbugs. The maximal abundance of invertebrates was noted in the substrate with eggs under a cover of netting - 292 spec/m^2 (device on sandy ground), the minimal abundance - 292 spec/m^2, was noted in substrate without eggs (device on stony-sandy soil).

Population by stonefly larvae was observed only in substrates with eggs.

Damaged empty egg shells were found. Determination of invertebrate species from the nature of damage to eggs in nature is rather doubtful (Fox, 1978). Identification of animals on a larger systematic level (caddis-flies, stoneflies, etc.) is possible on the basis of experimental study and observations in nature.

We may draw the following conclusions from the results obtained:

1. The presence of eggs in the substrate determines the greatest species diversity and a higher abundance of invertebrates by comparison with substrate without eggs;

2. Damaged empty whitefish egg shells are indicative of the ability of bottom animals to eat them; among the potential egg consumers we can include stonefly larvae, whose abundance was determined by the egg density in the experiment;

3. The low egg densities on spawning grounds by comparison with the experiment suggest that their consumption in natural conditions will be determined by the abundance of organisms which are capable of eating them.

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GROWTH OF RAINBOW TROUT AFTER X-RAY IRRADIATION IN EARLY ONTOGENESIS

By G.M. Persov and K.E. Fedorov
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The possibility has been shown of accelerating the growth of **Tilapia** (Tyong, 1970; Persov, Shirokova, 1975; Chmilevskii, 1984) by radiation suppression of the early stages of gametogenesis. There are also scattered data on the radiostimulation of the growth of the Persian sturgeon, the bester (Persov, Abrosimov, 1978), the carp (Cherfas, 1962) and some other fish species. The deciding conditions for obtaining the effect are considered to be the dose and initial condition of the organism at the time of irradiation. /246*

To analyze the dynamics of the postradiation growth in a series of experiments, rainbow trout larvae (at age 25 and 47 days) were subjected to one-time X-ray radiation at doses of 5, 25, 150, 350, 500 and 1000 R. The intact and irradiated fish were kept separately, but with identical planting density; food was given in excess. Control weighings were done at 1.5 - 3 month intervals for 14.5 - 22.5 months. /247

Analysis of the entire data set revealed the phase nature and common tendencies of change in the growth rate of trout for different irradiation variants. In the first 1-1.5 months after irradiation, a slight (at small doses) or reliable (at a dose of 1000 R) reduction in the growth rate was observed; later the weight increment of the irradiated fish was higher than in the intact fish, so that by the age of 3.5 - 4 months, the average mass of both was the same. The subsequent development of the radiation reaction depended on the radiation dose: at doses of 5-150 R, the deviations in growth rate were unstable and negligible; at a dose of 1000 R, a stable decrease in average mass was observed (to 30% of the control); while at doses of 350 and 500 R, at a

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number of stages of the observations in the 8-18.5 month age range, the irradiated fish overtook the intact fish in growth. The most pronounced and stable effect of radiostimulation of growth (20-45% higher than in the control), was in juveniles irradiated at a dose of 500 R at age 47 days, when, according to N.I.Zakharova (1985), trout undergoes one of the most sensitive stages in early gametogenesis, associated with the transition of the gametes from the mitotic to the meiotic cycle.

Thus the dynamics of the postradiation growth of fish suggest that the final radiobiological effect depends on the relationship of damage and reparation processes, between which there may not always be a close correlation: at a certain radiation dose, the strength of reparative processes can surpass the level sufficient to compensate for the damage caused by the radiation, and this in fact appears to be the functional basis of the effect of radiostimulation of growth.

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PHYLOGENY OF PACIFIC SALMONS: RESTRICTASE ANALYSIS OF MITOCHONDRIAL DNA

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The relationships of salmon fishes have been studied by many authors, although the opinions of investigators on this question have often been very contradictory. In recent years, the methods of molecular biology have come to be used in the analysis of relationships as being the most promising for the study of macro- and microevolutionary processes.

We evaluated the degree of affinity of salmon species using restrictase analysis of mitochondrial DNA. The rapid evolution and the peculiar manner of inheritance of mitochondrial DNA make it a more sensitive instrument than nuclear DNA for the study of phylogeny. We studied the phylogenetic relationships of six species of Pacific salmons of the genus **Oncorhyncus**, three species of the genus **Salvelinus**, one species of the genus **Parasalmo** and one species of the genus **Parahucho**. Mitochondrial DNA was analysed using restrictases Pst 1, Bam H1, Hind 111, Pvu 11, EcoR 1, Sal Q 1, Mva 1. The average number of study restriction sites for each species is 30, which is more than 1% of the mitochondrial genome of each individual. The seven restrictases used in the analysis of mitochondrial DNA vary the composition and length of restriction fragments and therefore include a sufficiently wide circle of nucleotide sequences.

The paired method of evaluating divergence in mitochondrial DNA sequences was used on the basis of similarity or difference of mitochondrial DNA fragments obtained by restriction. The estimates of variability of mitochondrial DNA of salmons are within the limits of those observed between closely related species of terrestrial vertebrates. A scheme of the divergence of the mitochondrial genome of salmon fishes has been constructed.

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GENETIC AND ENVIRONMENTAL DIFFERENTIATION OF INBRED LINES OF COREGONUS PELED BY PRODUCTIVITY CHARACTERS

By T.E. Rekst, M.A. Andriyasheva and E.V. Chernyaeva
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For both the fishery as well as for selection, the detailed /258* study of the acclimatized form of the peled which is bred at fish farms offers great interest. Such a study, which would include selection-genetic analysis, will help to solve certain methodological problems in the practical selection of the peled, and in particular to evaluate the genotypic and environmental components of the variability of productivity characters using the method of contrasting environments.

A study was done of females of inbred peled lines of the second inbreeding generation, cultivated in contrasting conditions: with high ("+" environment) and low ("-" environment) food supply. We studied closely correlated productivity characters - body mass (P), body length (L), body height (H), as well as the effective (R) and relative effective fecundity (R_o). In all lines, a 1.5-2 fold reduction in the average values of size-weight characters and the effective fecundity has been found on a background of food shortage. Investigation of the total phenotypic variability of the characters revealed differences in the coefficient of variation in the amount of variance both between lines and between environments. A tendency to increase in the variability of P, L, H and R has been noted in the "-" environment.

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Breakdown of the total variance by components using variance analysis allowed us to establish a substantial influence of genotype and environment on the study characters. Thus the contributions of the environmental and genotypic components respectively were 80.2 and 7.4% for P, 81.7 and 9.3% for L, 81.5 and 6.0% for H, 71.7 and 11.9% for R, and 8.3 and 22.9% for R_o, while body length also showed the influence of a "genotype-environment" interaction component ($p<0.05$).

According to the results of single-factor variance analysis, differentiation of inbred lines has been found in the magnitude of the contributions of environmental and genetic variability. The portion of environmental component was 82% for body weight, 90.4% for body length, 88.6% for body height, 71.0% for effective fecundity and 10.5% for relative fecundity. The contributions of the genotypic components of total variance in the "+" environment /259 were 36.7, 49.0, 59.1, 44.4 and 17.6% for P, L, H, R and R_o, respectively. An increase in the influence of genotype was mainly observed in the "-" environment - 47.5, 49.5, 32.0, 50.5 and 28.0%, respectively.

The use of covariant analysis revealed an influence of conditions of rearing and genotype on the combined variability of two pairs of closely correlated characters - "effective fecundity - body weight" (R-P) and "effective fecundity - relative fecundity" ($R - R_o$). It was noted that body weight and the relative fecundity of females has a considerable influence on the effective fecundity ($p<0.001$). It has also been established that genotypes also differ for R in the case when $P-R_o$ has identical values in the females of all lines. This allowed us to compare lines and to determine which of them will have greater productivity by the study of interrelationships and to determine the most promising among them for selection.

In order to study the influence of different conditions of maintenance on the magnitude and trend of correlations of the study characters, regression analysis was done for R-P and $R-R_o$ pairs, which showed that the correlations can differ both in different lines and in contrasting conditions of maintenance. It was established that for these pairs, the greatest diversity of lines was found in different environments: for the R-P pair, it was maximal in the "-" environment, while for the $R-R_o$ pair, it was the "+" environment which proved to be differentiating. The study performed of the ecologico-genetic structure of size-weight and reproductive characters and their correlations in inbred peled females offers the possibility of refining mass selection procedures by the main productivity characters.

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CHARACTERISTICS OF SEX DIFFERENTIATION AND FORMATION OF OOCYTE STOCK IN COREGONUS PELED UNDER DIFFERENT CONDITIONS OF CULTURE

By A.G. Selyukov
of Tyumen' State University.

It is known that the dates of sex differentiation in salmon /291* fishes are closely related to water temperature (Persov, 1969; Magomedov **et al.**, 1979; Lebrun **et al.**, 1982; Zakharova, Chmilevskii, 1984, and others). Moreover, the anatomical sex differentiation usually precedes the cytological. In whitefish, early gametogenesis has been studied to a lesser extent (Statova, Tomnatik, 1970; Gogolevas, 1983; Selyukov, 1985).

The material was collected in 1984-1985 at places where this species was introduced on the south of Tyumen' (Tyumen' whitefish nursery - TWN) and Leningrad ("Ropsha" TsES) oblasts. Sixty three peled larvae were fixed in the foraging pond at the TWN, and 239 larvae, fingerlings and young of the year at the "Ropsha". At the "Ropsha", juveniles were studied from a foraging pond and a "tank" which had been set up in a coldwater pond. The material was analyzed by the usual histological procedures. In studying the formation of the gamete stock in young of the year, we calculated the ratio (in %) of oogonia, oocytes in the early prophase of meiosis (meiocytes) and previtellogenic oocytes in cross-sections of gonads taking into account calculated correction factors.

At the TWN (with a water temperature of 18-22° and planting rate 23,800 fish/hectare), the peled at age 54 days with an average mass of 9.9±0.03 g showed anatomical differentiation of the gonads of the ovary type. Cytological sex differentiation began between 54 and 70 days. In the foraging pond at the "Ropsha" (17-

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20°; 2,500 fish/hectare), in the peled at 55 days with a mass of 3.3±0.10 g, anatomical and cytological sex differentiation in the female direction occurred simultaneously. In juveniles of the /292
experimental batch ("tanks") with a small amount of feed and temperature 9-13°, anatomical differentiation of the gonads began at 59, and cytological differentiation no sooner than 67 days at a mass of 0.15±0.04 g and continued until 103 days or later.

Thus, while the dates of anatomical differentiation of the gonads are more closely correlated with age, the onset of cytological differentiation is correlated to a greater degree with foraging conditions and the mass of fish.

In young of the year from the "Ropsha" with a high growth rate, which had by the end of the growing season (September) a mass of 96.8±3.90 g, the ovaries were the most developed and the total number of gametes and the dimensions of the older generation of oocytes (OOG) were the greatest of the compared variants, and the mitotic index had increased, which indicated the formation of a new generation of gametes. In these females, a positive correlation has been shown between the average diameter of the OOG's (the level of gonad development), and body dimensions (+0.65). In young of the year from the Tyumen' nursery with high rate of growth (10.6±1.20 g), the ovaries were less developed, and a low correlation was noted between fish size and OOG diameter (+0.42). The females of the experimental batch ("tanks") with the lowest growth rate (1.4±0.20 g) at the end of the foraging period had the least developed ovaries - the sexual cells consisted primarily of oogonia and meiocytes, and an insignificant number of previtellogenic oocytes was noted; no correlation was traced between body size and OOG diameter (+0.10).

Thus in fingerlings with a high growth rate, the level of development of the ovaries is closely correlated with body size, while for individuals with low growth rate from different geographic zones a weak development of the gonads has been shown, and the correlation of the level of development of the ovaries with body size was poorly expressed or absent.

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ECOLOGICAL PLASTICITY OF STAGES IN OOGENESIS OF COREGONUS PELED DURING SEXUAL MATURATION AND IN THE COURSE OF THE OVARIAN CYCLE

By A.G. Selyukov and A.M. Stepanov
of Tyumen' State University

The establishment of phases of oogenesis, the variation in /293* the duration of which determines the onset of maturation and the nature of the course of the sexual cycles, and determination of the range of their ecological plasticity in whitefish have been studied insufficiently. With the exception of single investigations (Kondradt, 1969), there has been no comparative analysis of the development of the gonads in whitefish from the natural ranges and those introduced into other climatic zones.

In the natural range, fixation of gonads was done in peled females maturing for the first time and sexually mature females in Lake Endyr' (Ob' R. basin) in 1981-1984 and in Lake Pyaku-to (Pur R. basin) in 1987; and at places were this species was introduced - at the ponds of the "Ropsha" TsES (Leningrad oblast') in 1983-1985. Three hundred forty five peled females were studied and ovaries of 264 served as material for histological and histochemical studies.

In the lakes of the natural range, peled females mature at 2+-4+, the bulk at 3+. Increase in the duration of previtollogenesis from 12-13 to 23 months with almost unchanged vacuolization phase (5-9 months) causes an increase in the duration of sexual maturation to 3+. The oocytes of the older generation (OOG) entered into the cytoplasm vacuolization phase during the summer or in the fall preceding the year of sexual maturation, while the accumulation of vitellus began in the spring, 6-7 months before spawning. The maturation of fish at 4+ is due to further lengthening of previtellogenesis.

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In conditions at the "Ropsha", the peled females mature at 1+ - 3+. Shortening of previtellogenesis to 9, and of the vacuolization phase to 1.5 - 2 months caused a maturation of the peled at age 1+. In such fish, the duration of previtellogenesis comprises 60.6% (of the total duration of pre- and vitellogenesis), the cytoplasm vacuolization phase 12.1%, and yolk accumulation 27.3% Retardation in the development of ovaries at the cytological differentiation stage, which can cause a delay in maturation to 3+ or older, has been noted in some year-old and second-year females.

There are certain peculiarities in the ovarian cycle in the peled from the natural range and from the "Ropsha". A prolonged period of low water temperatures in lakes Endyr' and Pyaku-to /294 determines a slow regeneration of the gonads after spawning and a prolonged residence of the OOG's in the phase of fine-grained yolk accumulation. In the "Ropsha" peled, vitellogenesis is also retarded in the gonads in the winter. With the onset of the growing season (a month earlier at the "Ropsha" than at Lake Endyr' and two months earlier than at Lake Pyaku-to), regenerative processes occur more rapidly in the females from the new range, and intensive vitellogenesis occurs throughout the foraging period. In the peled from the natural range, the regenerative processes in the ovaries continue until August, and vitellogenesis is completed at a high level and in a short period of time at the end of the summer. The described nature of vitellogenesis is determined by the peculiarities of the ecology of reproduction of the northern whitefish populations, which are situated for most of the year at low water temperatures and is probably one way of preventing the omission of spawning.

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COMPARATIVE KARYOLOGICAL STUDY OF DWARF MALES AND JUVENILES IN POPULATIONS OF ATLANTIC SALMON SALMO SALAR L.

By O.V. Semenova
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Dwarf males are usual in populations of Atlantic salmon, /294* as they are in those of other migratory salmons. At the same time, the mechanism of the appearance of dwarf forms has so far not been studied. Judgements on the significance, biological peculiarities and potentials for the utilization of dwarf males for fish culture purposes are contradictory. In particular, karyologists express different opinions as to the peculiarities of the karyotype of Atlantic salmon dwarf males. For example, Ya. V. Barshene (1979) considers that dwarf males have a higher variability of chromosome sets, especially in the generative tissues, and for this reason crossings of large migratory salmon females with dwarf males presents a serious danger in hatchery reproduction. Yu. P. Zelinskii (1985), on the contrary, notes the "correspondence" of the reproductive potentials of dwarf and /295 migratory males. It is obvious that a continuation of special genetic investigations, including karyological ones, will be required to solve the problems as to the role of dwarf males in populations.

We did a comparative karyological analysis of the chromosome numbers of dwarf males and juvenile salmon females, caught in June-July 1983-1985 in the rivers of the White Sea basin - the Umba, the Pyalitsa, and the Khlebnaya, as well as of fish taken at the Neva (Baltic Sea) and Svir' (Lake Ladoga) fish hatcheries. The work was done using the colchicine procedure. Kidney tissue was used for analysis. Sex was determined visually. The belonging of fish to the dwarf male group was judged from the condition of the

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gonads, which in these fishes showed clear signs of having matured in the last year. In this case, it was taken into consideration that the juvenile males could include individuals which would be able to mature as dwarfs in the following spawning season. Comparison of karyotypes was therefore done only between groups of dwarf males and juvenile females. In total, 112 fish were studied, of which 25 were dwarf males. The greatest number of dwarf males (7 fish), from which a sufficient number of metaphase plates was obtained was found in the Pyalitsa R. population. This group of fish was represented by single specimens in the other populations. For this reason, the basic comparison of chromosome complexes has been done for the example of the fish from the Pyalitsa R.

The modal chromosome complex of all the study specimens consisted of 58 chromosomes (16m, sm +42a), NF=74. A wide variability of chromosome numbers has been noted in both the dwarf males and the juvenile females: 2n=50-64, NF=62.76, cells with different chromosome sets being found with identical frequency:

	NF <74	NF=74	NF>74	fish	cells
dwarf males	30.6±3.81	65.3±3.94	4.1±1.64	7	147
juvenile females	27.2±3.68	67.3±3.88	5.4±1.87	7	147

The study fish groups also did not differ in the characteristics of the level of variability of chromosome sets (M - frequency of occurrence of cells of the modal type, A - aneuploid cells and R - cells of the class NF=74, but with chromosome number different from the modal: 2n ≠ 58): /296

	M	A	R
dwarf males	37.4±4.00	34.7±3.94	27.9±3.71
juvenile females	36.1±3.98	32.7±3.88	31.3±3.84

Similar findings were obtained in the study of specimens from the Umba, Khlebnaya and Neva populations. On performance of karyological analysis of the Atlantic salmon of the Svir' R., it was found that the great majority of individuals have the same modal karyotype as the fishes of the other study populations: 2n =58, NF = 74. However, three individuals from this population were found to have another chromosome set: 2n = 58, NF = 73. Here, a karyotype which differed from the modal was found not only in a dwarf, but also in a juvenile male and in a female. Thus we may not consider this peculiarity in the chromosome sets in this population as belonging only to dwarf males. It is possible that the karyotype (2n = 58, NF = 74 or NF = 73+1, since one chromosome was subtelocentric), which was previously described in the salmon of the basins of Lake Ladoga and Lake Onega (Zelinskii, 1985), is similar to that which we also found in some specimens of Svir' R. Atlantic salmon. The study performed shows that dwarf males differ from juvenile fishes neither in the basic characteristics of the modal karyotype, nor in the degree and limits of variability of chromosome sets. Apparently, those investigators are right who consider that the existence of dwarf males in populations is an

adaptation worked out in evolution to facilitate the maintenance of homeostasis. In this case, one should obviously not deny categorically the possibility of making use of dwarf males in the artificial formation of Atlantic salmon populations, especially since dwarf males take an active part in reproduction in nature.

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GENETIC STRUCTURE OF ATLANTIC SALMON POPULATIONS IN THE EUROPEAN PART OF THE USSR

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The Atlantic salmon **Salmo salar** L. has an extremely complex /297* and plastic morpho-ecological structure, which consists of a migratory and freshwater forms, a multitude of seasonal races and groups of dwarf males. Numerous studies have been devoted to it. The genetic structure of the species has received much less study. It is now known that the salmon stocks that spawn on both sides of the Atlantic are reproductively isolated and differ substantially in karyotypes as well as in the quantitative distribution of alleles of the transferrin locus (Payne, 1974). In addition, on the basis of analysis of the dynamics of the allele frequencies of this same locus, a celtic and a boreal race are distinguished in the British Isles (Payne **et al.**, 1971). Data are also available on the genetic divergence of the Baltic salmon (Stahl, 1986).

We present new findings on the nature of the hereditary variability of the proteins in salmon from the European part of the USSR and the genetic structure of its populations.

Material in the form of tissue samples was collected in 1978-1987 from fish of the spawning populations of the Neva, Narva, Gauya (Baltic Sea basin), Umba, Kola and Tuloma (basin of the White and Barents seas) rivers, as well as from hatchery groups of juveniles reared in Murmansk, Arkhangel', and Leningrad oblasts and the Latvian SSR (Table I). Natural juveniles were collected from the Kolvitsa (White Sea basin) and Ilych (a tributary of the

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Pechora, Barents Sea basin) rivers. The lake salmon **S. salar m. sebago** is represented by samples of juveniles of different ages from the Svir' fish hatchery (Lake Ladoga basin). In all, 9,266 sexually mature fish and 11,157 natural and cultured juveniles of the 1976-1986 generations were examined. Aqueous extracts of tissue samples were subjected to electrophoresis in polyacrylamide gel plates with subsequent histochemical exposure of EST-D, ME-2, IDH-1, MDH-3 and PO enzyme activity.

Analysis of variability of genetic markers showed that their /298
taxonomic value varies. Thus, EST-D is used to determine the species affiliation of the Atlantic salmon, the sea trout and hybrids between them (Slyn'ko, Semenova, 1980; Semenova, Slyn'ko, 1986). The system of transferrins has a similar property. Moreover, by means of it are tested not only the above-mentioned closely-related species (Nyman, 1967), but it has also been used to justify the existence in the Atlantic salmon of two subspecies (species?) - the American and the European. In contrast to these markers, as well as to naphthylacetate esterase and glucosophosphate isomerase, the polymorphous ME, IDH, MDH and PO contain in their electrophoretic spectra the products of allele genes that are common to the Atlantic salmon and the sea trout. It is just for this reason that these characters are unsuitable for systematic purposes. At the same time, analysis of their variability made it possible to detect clear genetic differences between the population sets of the rivers of the Baltic region and Leningrad oblast, the Kola Peninsula and the Onega-Pechora region. The lake (Svir') salmon occupies an intermediate position between the Baltic and Kola populations (Table 1).

A different genetic differentiation of the Atlantic salmon is observed with respect to EST-D. It is similar to that which is revealed for alleles of transferrins. We have established that the Kola Peninsula is the only place where polymorphism of EST-D has so far been found. The qualitative distribution of the EST-D alleles, which is traced in the series of all Atlantic salmon populations studied, therefore indicates the considerable reproductive isolation and genetic individuation of the Kola stock.

Thus the differences observed between genetically polymorphous qualitative characters, as well as between quantitative (morphological) ones reflect the peculiarities in the evolution of a given species, while the characters themselves have unequal value for the solution of systematic problems.

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DEVELOPMENT OF O. KETA AT LOW TEMPERATURES

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Investigation of the development of chum at low temperatures /303* is of interest in connection with the fact that often in the /304 selection of sites for construction of chum hatcheries little attention is given to the winter temperature of the water. Moreover, places are sometimes chosen with low water temperatures or, for example, not so long ago, they began to raise chum at some pink salmon hatcheries on Sakhalin.

Between 1984 and 1987, at a temporary shop at the Ryazanovka fish hatchery (southern Primor'e), experiments were done involving the incubation of eggs and rearing of chum fingerlings. The water supply was provided from drains laid parallel to the channel of the Ryazanovka R. The eggs were placed in incubation in the second half of October at a water temperature of 9°, and a slow decrease in temperature to 1.7° at the beginning of February was observed. This temperature held until the start of April and was followed by a slow increase in water temperature to 4° at the start of May. To use A.N. Kanide'ev's terminology (1984), the Ryazanovka hatchery can be considered warm-water, since the temperature of the water in the winter did not fall below 1.5°, but the prolonged (up to two months) period of temperatures of about 1.7° is very important in our opinion.

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Hatching began at the end of December and was completed by the middle of January. The eggs which had been laid in the last days of October developed more slowly. Hatching began at the end of January and was completed at the beginning of March, that is the process of hatching was very prolonged. The stage of seasoning of larvae before rising to swim in the first batch lasted about 40 days - to the end of February, and in the second batch -to the end of April - start of May - about 60 days. Rearing was done on dry granulated feed of the RGM-6M type. Due to the low temperature of the water, the juveniles of the first batch took 2 months to become accustomed to the feed and began to take feed only by the end of April - start of May, when the water temperature rose to 4°. Only at the end of May, when the water temperature rose to 6-7°, did the juveniles begin to feed actively. The juveniles of the second batch began to take feed also at the start of May, but began to feed actively at the end of May. As the result, the juveniles of both the early and late incubation had reached an average mass of 650 mg by the end of June.

Thus, with early incubation of eggs, the stages of seasoning and mixed feeding were prolonged, and with late incubation, the stages of hatching and seasoning of larvae. Juveniles from late incubation caught up in development to the juveniles from early incubation and active feeding began at practically the same time. /305
The later achievement by chum juveniles of size characteristics close to those of the natural population, which also means later release, must have a negative effect on the survival of hatchery juveniles in the first months of the marine period. The natural juveniles in the south of Primor'e migrate to sea mainly in April, when the maximal number of food organisms is noted on the coast, that is, conditions are good for growth and development.

Our materials thus indicate that in selecting sites for fish hatcheries for chum breeding, more careful attention must be given to the water temperature in sources in the winter-spring period or provision must be made for heating of the water, if it has low temperatures during this period.

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SOME APPROACHES TO THE PROBLEM OF MAINTAINING SALMON STOCKS

By A.I. Smirnov
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The Pacific salmon fishery every year removes an enormous /309* number of spawners from the spawning stocks. Its effect on the population is similar to that of mass selection. If the consequences of such a "selection" are not compensated for in time, quantitative and qualitative changes accumulate in the exploited populations. With the passage of time, they lose certain natural qualities and become increasingly artificial. The effects of irrational organization of the fishery intensify various disturbances in the regime of the spawning and growing bodies of water, whose qualities also change.

In the case of major removal of brood stocks and accumulating changes in the natural environment, the possibilities for the natural reproduction of stocks, on which the main reliance has been placed for a long time, are reduced. Accordingly, possible catches will increasingly be determined by the scale and effectiveness of fish management and improvement measures. It would be logical then to more actively involve in these measures the fishery organizations, who are more directly interested than others in the replenishment of stocks and who have moreover great technical and financial resources, which are clearly in short supply at fish management enterprises at the current level. The lack of participation of fisheries organizations in the replenishment of stocks has a negative influence on the development of salmon breeding and the salmon industry as a whole.

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It appears to be necessary to organize the fishery in such a way that the scale, content, time and place of fish management and amelioration measures are more closely tied in with the abundance of particular species, races and populations, the possibilities of their natural reproduction and the required (planned) replacement by artificial reproduction.

The further development of promising regional and basin programs of salmon breeding development remains pressing. These must include measures to ensure expanded reproduction and improvement of the quality of existing and creation of new populations, including by the introduction of valuable fisheries objects, which are able to reproduce in humanly altered conditions. The Far Eastern fishery must be oriented towards the large scale breeding of the most valuable commercial species - the chinook, the coho, the masu, the sockeye, and the autumn chum, and towards the replacement of summer chum stocks. This will require the creation of suitable nurseries, equipping of hatcheries with automated equipment, provision of adequate feeds and training of qualified personnel. We must put an end to the deliberate orientation of the Sakhalin fishery to the breeding of pink salmon, which has resulted in the conversion of a number of chum hatcheries to pink salmon ones. Trout breeding, lake, basin and tank rearing of salmon and char in fresh and salt water, in which we have fallen far behind our neighbours, must play a prominent role in the long term in the Far East. Particular attention must be given to the development of selection work. /310

Considering the unsatisfactory water supply of a number of fish hatcheries, including those built recently, we must provide for the introduction of circulating water works, conduct a wide search for plots suitable for the construction of fish breeding enterprises and perform long-term hydrological and hydrochemical observations at likely hatchery water supply sources.

In connection with shortcomings in the construction, equipment and correlation of fish breeding enterprises and water sources, we must have public discussion of their plans, for example at the Scientific Council on Salmonid Fishes of the Ichthyological Committee of the Ministry of Fisheries of the USSR.

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OSMOREGULATORY SYSTEM OF WILD AND CULTURED JUVENILES OF O. KETA DURING THE PERIOD PRECEDING THEIR SEAWARD MIGRATION

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A comparative study of osmoregulation in wild and cultured /319*
chum juveniles in the pre-migration period has been undertaken in order to develop criteria for the evaluation of the physiological condition of cultured juveniles during the release period and to determine the optimal conditions for the development of juveniles in the freshwater period. The degree of development of the osmotic homeostatic mechanism in the process of smoltification of juveniles to a large degree determines the degree of readiness for the marine way of life. We evaluated the ability of juveniles to maintain relative constancy of osmolarity of blood serum with change in salinity of the water from the dynamics of change in blood serum osmolarity in the process of adaptation of these juveniles to sea water with a salinity of 25-30°/oo after transfer from fresh water.

Chum juveniles from the Ado-Tymovsk hatchery (Sakhalin I.) /320
at the time of their release (length 41.8±0.2 mm, weight 489.0±10.0 mg) have limited salt resistance: they do not survive in sea water with a salinity of 30°/oo after direct transfer from fresh water; at salinity 25°/oo, the survival of juveniles after three days is 98%. The adaptation of juveniles to sea water at 25°/oo is achieved over a long period (10 days) and is accompanied by considerable fluctuations in the blood serum osmolarity: a considerable increase in blood serum osmolarity (by 28.1% above the initial) occurs in the first 12 hours of adaptation. This high level is maintained for the next 2.5 days, and a decline in the level of blood serum osmolarity sets in after 10 days of adaptation.

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Wild chum juveniles of the same population (Tym' R.) weighing 344.0±9.0 mg, with a length of 39.4±0.3 mm, are adapted to sea water with a salinity of 25 °/oo after three days with smaller fluctuations in blood serum osmolarity than cultured juveniles: in the first 12-24 hours of adaptation, the blood serum osmolarity rises by only 8.6% above the initial and returns to the initial level on the 3rd day of adaptation. A similar reaction of the osmoregulatory system to saline effect as in the wild juveniles can be observed in the cultured juveniles of the Ado-Tymovsk hatchery after they have achieved larger size (weight 595.0±5.0 mg, length 46.2±0.2 mm).

Chum juveniles of the Kalininsk hatchery (Sakhalin I.) with a weight of 296.4±0.,8 mg and a length of 37.2±0.4 mm in this same time adapt to sea water with a salinity of 30°/oo without wastage and with relatively small variations in the blood serum osmolarity: in the first 12 hours of adaptation, it rises to 13.5% above the original value, then decreases, so that after three days it amounts to 6.7%, and after 5 days 2.5% with respect to the initial state.

Wild chum juveniles of the Amur population (Bira R.) have a greater survival rate (45.7%) at salinity 30°/oo than do the juveniles of the Bidzhansk hatchery (25.8%). In adapting to artificial marine environment at salinity 30°/oo, the wild juveniles reduce the blood serum osmolarity more rapidly after its rise in the first 12 hours of adaptation.

The differences in the adaptation of wild and cultured /321
chum juveniles of each population to sea water are analyzed from the point of view of ecological histophysiology, on the basis of the study of the functional morphology of certain organs participating in osmoregulation. The adaptation to sea water of wild juveniles from two populations is analyzed from the point of view of differences in the ecology of the populations. Comparative analysis of the adaptation of wild and cultured juveniles indicates that the wild juveniles in the pre-migration period have a more developed osmoregulatory system than do the cultured juveniles, which in turn is indicative of substantial differences between hatchery and natural conditions of rearing.

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RATE OF DEVELOPMENT OF O. GORBUSCHA DURING EARLY ONTOGENY

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To determine the parameters of the dependence of the rate of /327* development of pink salmon in early ontogeny on temperature variables, we made use of observations at the Lesnoi LRZ (Sakhalin I.) in 1985-1986 and archival data for 1974-1985. Observations were made from the time of fertilization of eggs until the release of juveniles in three batches - beginning, middle and end of laying [incubation] - with daily measurement of water temperature. The development stages have been identified after A.I. Smirnov (1975). Tauti's equation (Mednikov, 1977) has been used to approximate the results of observations.

The value of the thermolability constant calculated from long-term data was 0.1055.

The values of the scale factor "A" for the three different pink salmon batches, whose development started in different temperature conditions, practically coincided when the next stage of development was reached.

When the scale factor "A" is used as a unit of age, the indices of linear growth of embryos and larvae did not depend on temperature and did not differ in the three batches. For embryos, the relationship between length and scale coefficient is described by a linear equation. For larvae, the relationship proved to be curvilinear. A deviation of growth from linear is noted from the time of readiness of larvae for mixed feeding. Differences in

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linear growth in embryonal and larval development are probably connected with limitations in energy delivery in the absence of external food and reduced egg sac resources. Depending on the food supply of larvae, their final length before complete resorption of the egg sac can vary considerably, reaching a maximum of 40-41 mm.

The juveniles achieved readiness for exogenous feeding at an average value of the scale factor of 260 days, at the time preceding the increase in temperature to optimal values at which the pink salmon larvae were beginning to feed. The pink salmon larvae of the first batches had completely resorbed egg sac already by the end of the first ten days in May. Optimal temperature /328
conditions on the coast for the release of juveniles (stabilization of temperature above 4°C), to which the natural downstream migration in fact coincides, are formed in this region in the third ten-day period of May - first ten-day period of June. Mechanical restraint of larvae can result in their exhaustion and death. We must incorporate in the biotechnical cycle thermoregulation of the rate of growth of pink salmon so that the time of achievement of readiness for active feeding by larvae and the onset of favorable conditions for the rearing of larvae coincide.

Calculations using the obtained scale factors characterizing the different stages of development have shown that in the case of thermoregulation, optimal development times will be achieved when the temperature from the time of laying is lowered to 6°C for 1.5 months. The incorporation of thermoregulation in the biotechnology of pink salmon breeding and the rearing of juveniles will contribute to a considerable increase in their hardiness and to the efficiency of the hatchery's work in terms of the final yield to the fishery.

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DETAILS OF GENETIC MONITORING OF CULTURED POPULATIONS OF THE ATLANTIC SALMON SALMO SALAR L.

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Breeding of Atlantic salmon is increasingly becoming the only alternative to the loss of this species in rivers which are subject to the anthropogenic influence. At the same time, the fish culture work itself, over the course of many years, can cause undesirable changes in the genetic structure and biological characteristics of fishes. In this connection, constant monitoring of the condition of Atlantic salmon populations which are influenced by breeding is necessary. /331* /332

The results are presented of work done in 1983-1987 at the Narva, Neva, Svir', Petrozavodsk and Umba fish hatcheries. At each of these, no less than 3 generations of Atlantic salmon were studied. Using electrophoresis in polyacrylamide gel, the distribution of the frequencies of the alleles of 6 polymorphous loci has been studied: $_{s}$Aat - 2, Sdh-1, Idh-3, Px, $_{m}$Me-2, Est-D. The stability of the genetic structure of populations was evaluated on the basis of differences in the frequencies of protein markers between generations (X^2-test).

The study showed that differences in the work of fish hatcheries largely predetermine the peculiarities of the genetic structure of populations. The use of a small number of spawners leads to instability in the population-genetic structure. Thus, at the Svir' fish hatchery (the annual number of spawners used no

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more than 10-40 spec.), differences between generations with respect to the frequencies of the alleles of 3 out of 4 polymorphous loci (Aat, Sdh, Me) are statistically reliable at a high level ($p<0.001$) of significance.

At the Narva fish hatchery in recent years a large number of spawners has been used (several hundreds) and the work is very effective. The yield to the fishery runs to 8-12% here (Kazakov et al., 1987). The differences observed in this case between generations with respect to the frequencies of alleles (Aat - $p<0.001$; Me- $p<0.05$; Px - $p<0.001$; Idh - $p<0.05$) are in all probability explained by the change at the start of the 80s in the conditions of maintenance of juveniles in the winter time (rearing in warm water). However, if the new breeding biotechnology remains unaltered and is improved [sic!], one can expect the genetic structure of the population to stabilize in a few generations.

The fish hatcheries which release into rivers juveniles in poor condition at times contrary to the usual migration dates, have a low effectiveness of work or do not show a commercial yield at all. Their effect on the reproduction of the Atlantic salmon in rivers in which natural spawning has been preserved is extremely slight. An example is the Umba fish hatchery, whose contribution to the abundance of the Umba R. population is no more than hundredth of a percent. Because of the fact that spawners from the natural population are used every year for laying of eggs for incubation, the characteristics of the Atlantic salmon juveniles cultivated at the Umba fish hatchery is only an indirect and rather approximate estimate of the condition of the naturally reproducing population. /333

These findings allow us to propose a differentiated approach to the organization of monitoring of cultured Atlantic salmon populations. Annual monitoring is required at fish hatcheries which use a small number of spawners or which rear juveniles in conditions which differ greatly from natural ones. Given high effectiveness of the fish hatcheries' work, stable genetic and other biological population indicators, monitoring data can be collected at 2-3 year intervals. Population monitoring in the case of low effectiveness of fish hatcheries' work and a large volume of natural reproduction in the corresponding rivers would make sense only after a radical change in the fish breeding work and sufficiently high commercial yield indices have been obtained.

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THE NATURE OF CHROMOSOME POLYMORPHISM IN SALMON FISHES

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At the present time, reliable data are available on the /345* karyotypes of many representatives of the two subfamilies of the salmon fishes - Salmoninae and Coregoninae. Analysis of our own and published data indicates that the karyotypes are variable to a different degree in the majority of species studied. The variability is of four types.

1. Robertson polymorphism is characteristic of the majority of representatives of the genera **Salvelinus, Parasalmo, Onchorhynchus** and **Coregonus.** It is expressed in the form of variability in the chromosome number with constant chromosome shoulder number. It is often accompanied by mosaicism of Robertson translocations. However, in some species of these genera, for example, sockeye and kundzha, the karyotypes are apparently not subject to Robertson polymorphism and are stable on the entire vast ranges of the species.

2. Variability of the nucleolus-organizing regions of chromosomes is detected by the use of Ag-staining. It has been noted in four of the six studied species of the genus **Oncorhynchus** - the sockeye, coho, masu, pink salmon and the mikizha of the genus **Parasalmo.** It is expressed in the form of size mosaicism of the nucleolus organizing regions of the chromosomes. This type of variability determines a substantial variation in size and morphology of homologous chromosomes having nucleolar organizers.

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3. Variability of accessory (B) chromosomes has been found in two species of the genus **Coregonus** - the chir and the Siberian cisco. It is expressed in the form of interpopulation differences (in the chir), intrapopulation polymorphism and mosaicism (in both species) in the number of B-chromosomes. Morphological and structural types of B-chromosomes are also very varied.

4. Heteromorphism of sex chromosomes has been found in five species of four genera - **Parasalmo, Oncorhynchus, Salvelinus** and **Coregonus**. In all species, the male sex is heterogametic. In **P. gairdneri, P. Mykiss and S. namaycush**, heteromorphism of sex chromosomes is poorly expressed, sex determining system XX-XY. Systems of multiple sex chromosomes $X_1X_1X_2X_2$ - X_1X_2Y and XX-XY_1Y_2 have been found in **O. nerka** and **C. sardinella.**

Data on the karyotypes of the graylings (Thymallinae) at present are less reliable. However they also indicate a high stability of the karyotypes of the graylings for chromosome number. The absence of clear boundaries between morphological types of chromosomes makes the index of the chromosome shoulder number artificial. The differences detected in the chromosome shoulder number are therefore unreliable. /346

Thus karyotype variability is very diverse in salmons. However, none of the types examined differs from those already known in other animals and plants and they are governed by common cytogenetic mechanisms.

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DYNAMICS OF TESTOSTERONE CONTENT IN THE BLOOD OF O. GORBUSCHA FROM THE KALININKA R. (SAKHALIN) AT FINAL STAGES OF ITS REPRODUCTIVE CYCLE

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The study of the blood sex hormone levels in salmons in the pre- and spawning periods offers practical interest in connection with improving the biotechnology of hatchery reproduction of these valuable fishes. /352*

Using the radioimmune method, we evaluated the free testosterone (T) content in ng/mL in blood of pink salmon spawners entering the Kalininka R. from the Tatarskii Strait in September to spawn. The nuptial dress is very pronounced in the fishes migrating from the sea. The condition of the testicles corresponds to the late III, IV and V stages of maturity, their coefficient is 1.1-11.5%, ejaculate volume 0.22 mL, sperm motility 4-5 points. The condition of the ovaries in females migrating from the sea corresponds to the IV stage of maturity, coefficient of maturity 13.5-18.3%. After a short (1-10 km) upstream migration, the spawners reach the spawning grounds, and after reproduction migrate downstream. In male kelts with gonads in the VI stage of maturity, the sperm is diluted and sperm motility is reduced to 0-2 points, and in female kelts a few residual eggs remain in the cavity. It has been established that the blood T level is 22.94-79.88 (42.56±3.79) in males with gonads in the late III stage of maturity and 15.71-53.69 (38.93±3.13) in individuals with gonads in the IV-V and V stages of maturity. The difference between the average levels in the fish of these groups is unreliable. The T level is 1.10-19.86 (7.66±1.62) in male kelts with gonads in the VI stage of maturity. The blood T level is highest - 111.59-292.92 (199.79±10.62) in females with gonads in the IV stage of maturity

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shortly before ovulation and spawning. The T level is 47.42 in females with gonads in the V stage of maturity caught at the spawning grounds and 1.17-24.71 (10.12±2.11) in female kelts with gonads in the VI stage of maturity. Thus spawners of both sexes do not show an increase in the blood T content in the transition of the gonads from the IV to the V stage of maturity, but after the end of the period of functional maturity (in the VI stage of maturity), the level falls considerably. These findings offer /353
a better picture of the details of hormonal regulation in the concluding stages of the reproductive cycle of the pink salmon.

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SEX STEROID LEVELS IN ATLANTIC SALMON AND SEA TROUT AT DIFFERENT STAGES IN THE LIFE CYCLE

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The content of free testosterone (T) and estradiol (E) in ng/mL has been determined by the radioimmune method in blood of parrs (P), smolts (S), large migratory specimens (LM) of salmon and sea trout from the Ponoi R., and also in freshwater sea trout specimens from the Mel'nichnii stream in June-July 1986-87. The steroid levels have been correlated with the condition of the gonads, estimated by specialized maturity scales (Murza, Khristoforov, 1984, 1985). In the sea trout from the Ponoi R., the average T levels in male S and LM with gonads in the I inactive stage of maturity (0.493±0.055 and 0.390±0.068) do not differ reliably from those in female S with gonads in the II stage of maturity (0.413±0.037), with gonads in the II-III stage of maturity (0.405±0.050), and LM with gonads in the early III stage of maturity (0.458±0.051). The T levels in P also do not differ reliably from those in S with similar condition of gonads. The average T levels in males with gonads in the I inactive stage of maturity and with an "attempt at spermatogenesis" (0.549±0.062), in females with gonads in the II stage of maturity (0.320±0.044), and with gonads in the II-III stage of maturity (0.426±0.075), and with gonads in the early III stage of maturity (0.437±0.013) from the Mel'nichnii stream are comparable with the T levels in the sea trout from the Ponoi R. with the same gonad conditions. The specimens of all the groups enumerated are characterized by relatively low levels of this hormones in the range 0.037 to 0.847. Higher limit and average T levels have been detected in males maturing for the first time and repeatedly maturing males in the /353*

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transition of the gonads to the early III or VI - early III stages, and in females maturing for the first time and repeatedly maturing females on the transition to the late III or VI - late III stage of maturity. For example, in males maturing for the first time from the Ponoi R., the T content is 0.695-2.385 (1.527±0.233), in those from the Mel'nichnii stream 0.635-5.933 (2.545±0.497), while in repeatedly maturing males from the same bodies of water, the T levels are 0.124-11.355 (3.932±1.635) and 0.382-9.346 (2.301±0.675). In females maturing for the first time from the Ponoi R. and the Mel'nichnii stream, the T level is 0.702-0.716 and 0.399-2.135 (1.279±0.190), and in repeatedly maturing females 0.199-3.685 (1.463±0.911) and 0.811-3.268 (1.470±0.520). /354

Average E levels which are low and close to each other have been detected in the study of sea trout from the Ponoi R. in female P and S with gonads in the II stage of maturity (0.057±0.012 and 0.054±0.005), with gonads in the II-III stage of maturity (0.055±0.005 and 0.053±0.005), in LM with gonads in the II-III stage of maturity (0.058±0.010) and with gonads in the early III stage of maturity (0.059±0.005), as well in male P, S and LM with gonads in the I inactive stage of maturity (0.051±0.010; 0.055±0.005 and 0.051±0.006) and with gonads in the early III stage of maturity (0.054±0.007). In female sea trout from the Mel'nichnii stream with gonads in the II stage of maturity, the E level is 0.062±0.002, in those with gonads in the II-III stage of maturity 0.072±0.006, in those with gonads in the early III stage of maturity 0.063±0.002. Similar E levels have also been noted in repeatedly maturing males with gonads in the VI - early III stage of maturity from these bodies of water (0.070±0.007 and 0.083±0.005). The greatest limit and average E levels have been found in females with gonads in the late III stage of maturity both from the river 0.140±0.907 (0.477±0.126) and from the stream 0.070-1.478 (0.538±0.181). In females in the VI - late III stage of maturity, higher E levels have been noted in the sample from the stream 0.060-0.789 (0.551±0.130) than from the river 0.040-0.059 (0.049±0.005).

In the Ponoi R. salmon, the male P and S with gonads in the I inactive stage of maturity (0.415±0.207 and 0.355±0.035) and with gonads in the VI-I inactive stage of maturity (0.277±0.139), as well as female S with gonads in the II stage of maturity (0.715[?]±0.046) and female kelts with gonads in the VI - early III stage of maturity (0.223±0.051) have relatively low average T levels. Higher average T levels have been noted in males of the summer run and those which have overwintered in the river with gonads in the early III stage of maturity (1.710±0.303 and 0.873±0.180), and in females off the summer run and those which have overwintered in the river with gonads in the late III stage of maturity (1.094±0.107 and 0.851±0.100). Average E levels are low in salmon S, in particular in females (0.067±0.004); they are somewhat higher in female kelts (0.091±0.12), and also in males of the summer run (0.109±0.053) and those which have overwintered in the river with gonads in the early III stage of maturity

(0.088±0.011). The greatest average E levels have been found in the females of the summer run (2.572±0.383) and those which have overwintered in the river with gonads in the late III stage of maturity (2.533±0.399). In females with mass atresia of the ovarian follicles, the T level is high (1.83), while E is low (0.234). The role of T and E in the regulation of gametogenesis and smoltification is discussed.

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POPULATION GENETICS PRECONDITIONS FOR THE FORMATION OF PRODUCTIVE STOCKS OF RAINBOW TROUT IN KAZAKHSTAN

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Selection work with rainbow trout was organized in 1985 and is now rather intensive at the Turgensk trout farm (Kazakhstan). The farm is situated in the foothills of the Zailiiskii Ala-Tau and is fed by water from the Turgen' mountain stream, which has low temperature indices which do not exceed 14°C on the hottest days; the predominant temperatures in the summer are 10-11°C. The heat deficit throughout the fish rearing period has a negative effect on their growth and other breeding indices. The main task of the selection work being done at the farm is therefore to improve the productive qualities of the rainbow trout in low temperature conditions. /355*

As initial breeding stock, we used two genetically different groups of fish - local Turgensk trout (T) of mixed origin and American Donaldson's trout (D), imported to the farm in 1982 as eggs from Japan. According to available information, the Donaldson's trout represents a cultured form (breed), derived by purposeful selection over several decades and having high productivity potentials. The temperature optimum at which this form shows its best qualities is about 18°C.

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At the first stage of selection work, by means of reproduction "within itself"and subsequent separate rearing, two rainbow trout populations (stocks) of approximately equal abundance comprising all age groups from fingerlings to repeatedly spawning adults, were /356 formed. In order to determine the most effective direction for the utilization of the trout genofond which had developed at the farm, reproductive interpopulation crossings (TxT, DxD, TxD, DxT), in which 100 females and 30 males from each population participated, were arranged in parallel with the reproduction of the two populations. This enabled us to do a comparative assessment of the two trout populations for their adaptation to the specific conditions of the Turgensk farm, and to establish four breeding lines on the basis of selection among the resulting progenies.

Observations on the development and growth of the fish in different life periods showed that differences in the reaction norms in the two trout forms to the same environmental conditions show up rather clearly against the background of the determining influence of quality of feeding and thermal regime on breeding indices. These took the form of differences in trout T from trout D with respect to a large number of morphophysiological traits. For instance, given identical size of fish, the average fecundity of three- and four-year-old female D was 60.4% and 54.3% higher, respectively, than the fecundity of female T. These differences are 33.6% and 27.5%, respectively, for relative fecundity. Of 47 study quantitative characters, reliable differences have been found in 20. The total phenotypic variability of trout D considerably surpasses that of trout T - the coefficients of variation in the former had larger values for 33 out of the 47 traits. But the two trout forms differ to the greatest degree in viability in the first year of life. The complete superiority of trout T is seen here, which indicates its better adaptation to the conditions of the Turgensk farm.

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A METHOD OF IMPROVING EFFICIENCY AT FARMS PRODUCING O. GORBUSCHA BY A CHANGE IN THE STRATEGY OF CROSSING SPAWNERS

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It was only recently established that in Pacific salmon /362*
of the genus Oncorhynchus, including the pink salmon O. gorbuscha (Walbaum), spawners of different size differ in the /363
viability of offspring (Chebanov, 1984). The existence in pink salmon has also been found of a phenomenon of positive assortative crossing, which is determined by the body length of spawners, which consists essentially of the preferential natural crossing of individuals of similar size (Chebanov 1984a). However, the functional significance of this phenomenon for the populations of the pink salmon was not understood.

In order to solve this problem, in 1981, 1983 and 1984 at the Karymaisk spring (basin of the Bol'shaya R., Western Kamchatka), we did a series of individual artificial crossings of pink salmon spawners of different size with subsequent incubation of offspring, karyological analysis and analysis of mortality of progeny at different stages of development. On the basis of the number of aberrant cells and cytogenetic disturbances, we divided the embryos into three groups: I - embryos with relatively low (up to 10%), II - with average (up to 25%) and III - with high (more than 25-30%) level of cytogenetic disturbances. For salmons having polyploid origin, the existence of a comparatively small number of aberrant cells (up to 10% per embryo), obviously can not

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substantially affect their viability (Kaidanova, 1984; Mantel'man et al., 1980). The majority of embryos with a high level of chromosomal anomalies (more than 30% aberrant cells per embryo) should be eliminated in the early stages of embryogenesis, while those with average level can survive until the later stages, although in this case they have a relatively low viability and obviously will die more often than the others in the case of unfavorable environmental factors (Burtsev, Serebryakova, 1980). The fact that chromosomal anomalies are not found in adult pink salmon favors this proposition (Gorshkov, Gorshkova, 1981).

Analysis of the mortality of pink salmon embryos to the "eye" stage in different crossing variants showed that on the average in all years, within the small female size class, the offspring from the crossing of small females with small and large males; within the medium sized female class, those from the crossing of the latter with medium-sized males; and in the large female class, those from the crossing of the latter with large males had the lowest mortality. That is, the overall picture obtained in our opinion provides a fully acceptable explanation of the functional significance for the population of the phenomenon of positive /364
assortative crossing. In situations where it is predominantly spawners of similar size that are crossed, the effectiveness of spawning increases substantially, since the average level of viability of offspring is increased. The crossing of small females with large males, representing a component of negative assortative crossing, which can also occur in pink salmon in certain conditions of spawning, usually has the same result (Chebanov, 1984a).

These conclusions are borne out well by the results of cytokaryological analysis. The frequency levels of chromosomal anomalies in crossings turned out to be rather closely correlated positively with the mortality levels of embryos to the "eye"stage. This applies to both the second and the third type of disturbances and to the total of both together. We are right to expect then that the differences in the viability of offspring from the crossings of spawners of different sizes, which have been noted at the embryonal stages, for genetic reasons alone will persist and deepen at later stages, including obviously the salt water period of life as well.

These results undoubtedly can and should find a practical application, primarily in salmon breeding. At present, spawners are not sorted by size before artificial fertilization; mixed stock is used. Using these crossing methods, the average mortality of pink salmon eggs at the Sakhalin hatcheries is about 5% over the incubation period (Rukhlov, 1982). According to the results of our studies, an appreciable decrease in this value can be achieved. The use of "regulated"crossings: small females x small and large males, medium-sized females x medium-sized males, large females x large males, will enable these enterprises with average pink salmon egg incubation levels of 400 million eggs (Rukhlov, 1982) and an average coefficient of return from released juveniles of 1.97%

(Rukhlov, 1980), to obtain an additional effect of 0.494 to 0.964 million adult fish or in weight terms, of 667 to 1301 tonnes of raw material. The proposed method will thus provide the possibility of raising the efficiency of pink salmon rearing establishments by 6.6-9.4%, with the only additional expenditures required being the introduction of preliminary sorting of spawners before crossing.

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THE INFLUENCE OF LOWER TEMPERATURE ON THE DEVELOPMENT OF THE REPRODUCTIVE GLANDS IN THE EARLY ONTOGENY OF RAINBOW TROUT (SALMO GAIRDNERI)

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Temperature is one of the most important factors influencing /377* the growth and reproduction of different fish species. Development of the most favorable temperature regimes for the rearing of rainbow trout juveniles, knowledge of their limits and the effects of extreme temperatures on the morphophysiological condition of fish is of great practical importance.

To study the effect of low temperature, we seasoned trout larvae at a temperature of 3-4°C from the age of 13 days after hatching to 78 days. Some of them were transferred at the age of /378 50 days to water with a temperature of 15-18°C (similar to control conditions). The experiment lasted 4 months. All the results obtained were subjected to the usual histological analysis. In addition to the development of the gonads, changes in the weight indices of the control and test fish were traced.

As a result of these experiments, it has been established that the development of the gonads in the control fish coincided to the dates established in previous experiments and to published findings. Within 40 days after hatching, oocytes in the early prophase of meiosis and signs of anatomic differentiation of the gonads in the female direction appeared. Oocytes of the previtellogenesis period began to appear after 78 days. The prolonged maintenance of rainbow trout larvae at low temperature caused a marked delay in the rates of development of the sex

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glands. The gonads of the test fish contained mainly primary sexual cells (PSC) until 78 days after hatching, and reproduction of the gametes practically did not occur. The sex glands did not increase in size and anatomical differentiation of the gonads was also not observed. Death of the test fish was observed at this age. When larvae were reared in normal temperature conditions, compensatory development of the gonads was observed in parallel with compensatory growth of the fish beginning at age 50 days (stage 35-36 after Vernier). As a result, the gonads of the test fish reached the control level of development.

Thus, the early gametogenesis of the rainbow trout (the gonads contain predominantly PSC at the very start of mitotic divisions) is sensitive to the effects of low temperature, which blocks the reproduction of the gametes and the development of the gonads. The depressive effect of low temperature on growth and development of fish gonads can be completely removed if the period of its influence does not exceed 37 days.

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DYNAMICS OF ION CONTENT OF BLOOD IN JUVENILE SALMON IN WATER WITH INCREASED ACIDITY.

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The progressive acidification of fresh waters is a real threat to the ichthyofauna inhabiting such waters. In particular, for younger salmon (larvae, fry), the lower limit of acidification is considered to be a pH of the water of about 4.5. /381*

It was previously established (Matei, 1979) that the main effect of high acidity of the environment on fish consists in the appearance of serious destructive changes in the gill epithelium, which ensures ion exchange in fish, and associated disturbances in ion exchange regulation.

In this work, we studied the effect of acidification of the environment on the ion content of blood of juvenile salmon **Salmo salar** L. (yearlings, average weight 10.5 g) and its dynamics in the course of 6-day adaptation to water with a pH of 5.0 - 5.1, and during 4 days after they had been returned to water with a pH of 6.8-6.9. Na^+, K^+, Ca^{++} ions in blood of fish were determined by flame photometery; acidification of the environment was created by the addition of hydrochloric acid to the water. The work was done at the "Kartesh" White Sea Biological Station of the Zoological Institute of the Academy of SCiences of the USSR.

The experiment showed:

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potassium. No substantial deviations from the original potassium levels have been noted throughout the experiment. This is obviously due to the important role of potassium homeostasis in maintaining the normal vital activity of the organism.

sodium. Fifteen minutes after the start of the experiment, a decrease in blood sodium progessing over four days to 20% of the original level was noted, after which this process stabilized. According to B.E. Matei, a destruction of branchial spaces, creating a condition for maximal loss of sodium from the organism, is noted at this time. The sodium content of the blood is gradually restored after the fish are transferred to water with normal acidity.

calcium. Fifteen minutes after the start of the experiment, an increase in blood calcium was noted. It persisted throughout the period of adaptation to water with increased acidity. It decreased abruptly when the fish were transferred to water with a pH of 6.8-6.9.

As causes for these changes in blood calcium in salmon /382
directed at compensatory restoration of ionic homeostasis, we may propose the following:

1. Entry into the blood of Ca++, liberated in the destruction of intercellular spaces in the gill epithelium of the fish.
2. Mobilization of Ca++ from existing depots (scales and bone).

On transfer of fish to water with normal pH, restorative processes can cause a decrease in blood calcium.

It is known that disturbances in ionic regulation in fish are associated with a decrease in the osmotic pressure of the blood and in the electrolyte content of the organism, as well as with changes in metabolic processes entailing a retardation in the growth of the fish.

This makes clear the need for studies to determine the limits of environmental acidity in which breeding and rearing of salmon can be done, as well as for studies to predict the condition of ichthyofauna in different waters having for various reasons a tendency to changes in the chemism of the water.